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FISCAL YEAR 1996 NASA AUTHORIZATION

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HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SPACE AND AERONAUTICS

OF THE

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

FEBRUARY 13; MARCH 16, 1995

[No. 8]

Printed for the use of the Committee on Science

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FISCAL YEAR 1996 NASA AUTHORIZATION

MONDAY, FEBRUARY 13, 1995

House of Representatives,
Committee on Science,
Subcommittee on Space and Aeronautics,
Washington, D.C.

The subcommittee met, pursuant to call, at 12:30 p.m. in Room 2325, Rayburn House Office Building, Hon. F. James Sensenbrenner, Jr. [chairman of the subcommittee] presiding.

Mr. Sensenbrenner. The Subcommittee on Space and Aeronautics will come to order. Today I want to welcome our witnesses, Mr. Daniel Goldin, Administrator of NASA, Mr. Frank Weaver, Director of the Office of Commercial Space Transportation, and Mr. Keith Calhoun-Senghor, Director of the Office of Air and Space Commercialization.

Mr. Weaver and Mr. Calhoun-Senghor will give us insight into the commercial launch market and U.S. opportunities in commercial space. Mr. Goldin will brief us on the dramatic changes that are in store for NASA.

The agency was notified on January 12th that it was to take reduction in the out years that amount to $5 billion over five years. Mr. Goldin plans to accomplish this major feat through a restructuring of NASA.

This will indeed be a major undertaking if we are to realize the savings that President Clinton has mandated. While I encourage efforts to consolidate activities and eliminate duplication, I temper this enthusiasm with a concern for how this will play out in particular programs and amongst NASA employees.

Specifically, I want Mr. Goldin to say that he is personally confident that the Shuttle Program is safe, that the cuts have not come so deep or so quick that we are unable to determine whether the line of safety has been crossed.

NASA has a history of overoptimistic planning. This typically results in rescoping and downsizing programs after the programs have already been approved. That is why I have such grave concerns about NASA initiating any new starts in this budget cycle.

Although there is little doubt that SIRTF and SOFIA have scientific merit, I am skeptical of this agency's ability to pay for programs that have complete program costs of between $250 and $650 million. NASA has only requested $63 million to start them in fiscal year 1996, but now the camel's nose is under the tent. What NASA must not do is initiate programs for which it cannot pay, particularly in the out years.

It is painfully obvious that NASA must develop a long-term budget plan that takes into account its long history of programmatic cost growth and the funding shortfalls that it will encounter throughout the rest of this decade in order to realistically meet the challenges of the next century.

Although NASA has experienced budget cuts over the past several years, the mindset in the President's budget shows that it has not undergone the necessary change from the free wheeling glory days of the past. To achieve the maximum return, the agency must now leverage its resources through cooperative arrangements with private industry, international entities and other Federal agencies.

The Reusable Launch Vehicle Program is a prime example of how to move towards that goal. It is intended to be an industry-led cooperative venture. The challenge for NASA will be sticking to the ideals expressed in the cooperative agreement notices.

On the opposite end of the spectrum is NASA's failure to incorporate the highly relevant technology of the Ballistic Missile Defense Organization. NASA should not only seek to avoid duplication inside the agency, but also to avoid duplication outside the agency. NASA should be blazing those trails that have not been blazed before.

Rest assured, I will be keeping a close watch on the programs of NASA that attempt to duplicate that which already has been done by BMDO. This failure should not necessarily be laid at the doorstep of the current administrator, but rather the machinations of the internal politics of an agency that views every new program as a source of extended employment.

Although I have stated that the RLV Program is an example for the future, it has fallen prey to the current environment of NASA, and that has got to stop. This week's Space News makes reference to a letter sent by Chairman Walker to Administrator Goldin.

Mr. Walker is concerned that a layer of go-between management types are forming at the Marshall Space Flight Center. I am glad to see that NASA has gotten the message. NASA now is saying that there will be no layer between the program manager and the flight project managers.

I look forward to a very productive session today and now I would like to recognize the Ranking Minority Member, Mr. Hall, the gentleman from Texas.

Mr. HALL. I thank the Chairman and I would first like to really wish you well as you assume the chairmanship of this subcommittee. I can't think of anyone—if you were not the Chairman, I can't think of anyone that I would rather see as Chairman unless it would be Mr. Calvert or Mr. Weldon, Mr. Stockman, Mrs. Seastrand.

Seriously,—

Mr. SENSENBRENNER. If the gentleman will yield, are you prognosticating to 1996 and beyond?

Mr. HALL. Seriously, Jim Sensenbrenner has been a real stalwart on this committee and has been the eyes and actually the advice for the committee because he has given us his time to go to the places that some of us neither had the inclination nor the time to visit and brought back the results and they have been very helpful.

I think I have five minutes for an opening statement and I would yield to Chairman Brown if he has anything to say.

Mr. BROWN. Thank you very much, Mr. Hall. I share your high regard for Mr. Sensenbrenner and look forward with confidence to his leadership.

Let me just make one very brief statement which will in a sense corroborate what Mr. Sensenbrenner has already said. We cannot cut the NASA budget in the manner contemplated, keep trying to do everything in the current program and start new activities. We will have to make painful choices.

I know that the NASA Administrator believes that restructuring the space program may avoid the need for such choices, but I remain skeptical. And may I ask unanimous consent to put the rest of my excellent statement in the record at this point.

Mr. SENSENBRENNER. Without objection.

[The Prepared statement of Mr. Brown follows:]

OPENING STATEMENT

by

HON. GEORGE E. BROWN, JR.

I MUST CONFESS THAT I AM DEEPLY DISAPPOINTED BY THE DECLINING SPACE BUDGET PRESENTED TO THE CONGRESS LAST WEEK. WHILE I BELIEVE THAT THE PRESIDENT HAS MADE A GOOD FAITH EFFORT TO FIND MONEY TO CONTINUE THE FEDERAL GOVERNMENT'S INVESTMENT IN SCIENCE AND TECHNOLOGY, I FRANKLY THINK THAT AS A NATION WE ARE NOT DOING ENOUGH TO MAINTAIN THAT VITAL INVESTMENT. WE CERTAINLY ARE NOT ON A PATH THAT WILL ALLOW US TO ATTAIN THE GOALS CONTAINED IN THE ADMINISTRATION'S NEW SCIENCE POLICY.

MOREOVER, I FEAR THAT THE PRESIDENT'S PROPOSED BUDGET WILL BE A HIGH WATER MARK, AND THAT THE CONGRESS IS LIKELY TO CUT FUNDING FOR SCIENCE AND TECHNOLOGY EVEN MORE. INDEED, LAST WEEK'S RECISSION PACKAGE CONFIRMS TO ME THAT SCIENCE AND TECHNOLOGY WILL BE ASKED TO PAY A DISPROPORTIONATE PRICE AS THIS CONGRESS LOOKS FOR MONEY TO PAY FOR TAX CUTS AND DEFENSE INCREASES.

THE NASA BUDGET IS A CASE IN POINT. THE FY 96 BUDGET REQUEST PROJECTS A DECLINING NASA BUDGET OVER THE NEXT FIVE YEARS, DOWN TO A LEVEL OF $13.1 BILLION BY FY 2000. WHEN INFLATION IS TAKEN INTO ACCOUNT, THE "BUYING POWER" OF THE FY 2000 NASA BUDGET HAS SHRUNK TO A LITTLE MORE THAN $11 BILLION IN FY 95 DOLLARS--A 23 PERCENT REDUCTION FROM THE FY 95 APPROPRIATION. MOREOVER, THE TREND FOR SPACE SCIENCE, WHICH CONCERNED ME SO MUCH DURING LAST YEAR'S BUDGET DEBATE, CONTINUES TO BE NEGATIVE. AND YET, EVEN THIS FUNDING LEVEL FOR NASA AND FOR SPACE SCIENCE IS BY NO MEANS SECURE GIVEN THE CONTINUING BUDGETARY PRESSURES ON CONGRESS.

I HOPE THAT THIS POSTURE HEARING WILL CONFRONT THE ISSUE OF PRIORITIES. IF THE NASA BUDGET IS TO BE CUT, IT IS BECAUSE WE HAVE CHOSEN TO MAKE IT A LOWER PRIORITY THAN SOME OTHER ACTIVITIES, NOT BECAUSE SUCH CUTS ARE INEVITABLE. AT HIS FIRST PRESS CONFERENCE, CHAIRMAN WALKER ANNOUNCED HIS INTENTION TO SEEK AN INFLATIONARY INCREASE TO THE NASA BUDGET. HE REITERATED THAT INTENTION IN A RECENT INTERVIEW. I APPLAUD THAT COMMITMENT AND HOPE THAT HE WILL BE ABLE TO CONVINCE HIS REPUBLICAN COLLEAGUES TO FOLLOW HIS LEADERSHIP ON THIS ISSUE.

WE NEED TO BE CLEAR ABOUT THE ALTERNATIVE IF MR. WALKER IS UNSUCCESSFUL. WE CANNOT CUT THE NASA BUDGET IN THE MANNER

CONTEMPLATED, KEEP TRYING TO DO EVERYTHING IN THE CURRENT PROGRAM, AND START NEW ACTIVITIES. WE WILL HAVE TO MAKE PAINFUL CHOICES. I KNOW THAT THE NASA ADMINISTRATOR BELIEVES THAT RESTRUCTURING THE SPACE AGENCY MAY AVOID THE NEED FOR SUCH CHOICES, BUT I AM SKEPTICAL.

CERTAINLY WE SHOULD BE TRYING TO MAKE NASA MORE EFFICIENT AND EFFECTIVE. CERTAINLY WE SHOULD BE EMBRACING NEW TECHNOLOGIES. HOWEVER, IT IS A CLEAR EXAMPLE OF THE MISMATCH BETWEEN PROGRAMMATIC ASPIRATIONS AND RESOURCES PROVIDED, THAT UPDATING NASA'S TECHNOLOGIES SHOULD BE SEEN AS A BOLD NEW INITIATIVE INSTEAD OF WHAT NASA SHOULD BE DOING AS PART OF ITS BASIC MISSION.

THIS BUDGET INCLUDES A NUMBER OF NEW STARTS. THEY ALL APPEAR TO HAVE SOME MERIT. YET IF WE ARE GOING TO CONTINUE TO CUT NASA YEAR AFTER YEAR, WE NEED TO DECIDE WHETHER IT MAKES SENSE TO ADD ADDITIONAL ACTIVITIES--NO MATTER HOW LAUDABLE--BEFORE WE HAVE IDENTIFIED HOW WE WILL PAY FOR THEM.

I HOPE THAT THIS HEARING WILL HELP US TO MAKE REASONABLE POLICY DECISIONS ON THE FUTURE OF THE U.S SPACE PROGRAM.

Mr. HALL. Mr. Roemer, yield to Mr. Roemer whatever time he needs up to 30 seconds.

Mr. ROEMER. I would just ask unanimous consent that my prepared statement be entered into the record and that I ask the distinguished new Chairman that we be able to submit questions in writing and get a prompt response to those written questions.

Mr. SENSENBRENNER. Without objection, the gentleman's statement will be included in the record, and just to state that in the policy that I enunciated to the committee at its opening session, questions in writing directed to any of the witnesses shall be submitted to the committee staff within one week following the hearing and we would ask the witnesses to respond within 10 business days after receipt of the written questions so that the hearing record can be closed and the hearings published and distributed.

[The prepared statement of Mr. Roemer follows:]

Opening Statement, Rep. Tim Roemer, Subcommittee on Space, February 13, 1995

Mr. Chairman, it seems every year we find ourselves here saying that NASA is at a crossroads.

In this session of Congress, we have been trying to reset our national fiscal policies and priorities, with some real success.

But with these budgetary realities must come sacrifices. Part of the reason we are here today is to determine what NASA's sacrifice will be. Are we asking too much? Are we not asking enough?

And how are we to adjust the NASA budget with ever tighter resources with this golden calf in their budget that we may never touch? I refer, of course, to the space station.

Last year, with "management efficiencies" and restructuring, NASA -- we were told -- cuts its budget to the bone. Now we see that they must absorb $5 billion in new budget reductions.

The NASA Administrator says we need "fundamental restructuring." The Speaker of the House says that we should have privatized the space program after the APOLLO mission.

Just where are we going? And why does the NASA budget create more questions every year? What kind of space program can we expect in the next century?

Mr. Chairman, I do not expect to hear answers to any of these questions here today, although I certainly think I should. It is my hope that we will find out these answers in the coming months, or there may be no space program in the coming years.

I also understand that this may be our one shot at Administration witnesses this budget season. I would urge the Chairman to reconsider. If the space agency is to undergo any radical renovation, then this panel has a deep responsibility to follow these changes closely, and NASA needs to report to us on a very regular basis.

I would urge Mr. Hall, our Ranking Member who has been such a tremendous leader of this subcommittee in past years, to join me in this call for regular oversight hearings as NASA works to define and fit into the role it will play in our nation into the next century.

Mr. ROEMER. I would only say, does that include my negative questions about the space station as well, Mr. Chairman?

Mr. SENSENBRENNER. That includes any question the gentleman from Indiana might like to ask, either very perceptive or extremely dumb.

Mr. HALL. Mr. Chairman, I am not sure that you haven't used up all my time, but because of the caliber of the witnesses and the value of their time and your interest of getting a timely start, I just ask unanimous consent to put my opening statement and I yield back my time.

Mr. SENSENBRENNER. Without objection.

[The prepared statement of Mr. Hall follows:]

OPENING STATEMENT

by
HON. RALPH M. HALL

NASA POSTURE HEARING
February 13, 1995

GOOD AFTERNOON. I'D FIRST LIKE TO TAKE A MOMENT TO WISH MR. SENSENBRENNER WELL AS HE ASSUMES THE CHAIRMANSHIP OF THE SUBCOMMITTEE. HE HAS BEEN A HARDWORKING AND RESPONSIBLE RANKING MEMBER, AND I AM SURE HE WILL DO A GOOD JOB AS CHAIRMAN UNTIL WE SWITCH POSITIONS AGAIN IN TWO YEARS.

I'D ALSO LIKE TO WELCOME THE NEW FRESHMEN MEMBERS. I'VE BEEN IMPRESSED WITH THEIR BACKGROUNDS AND THEIR ENTHUSIAM, AND I BELIEVE THEY WILL BE A REAL ASSET TO THIS SUBCOMMITTEE.

ANYONE WHO HAS SEEN THE REDUCTIONS CONTAINED IN THE NASA BUDGET REQUEST KNOWS THAT THIS SUBCOMMITTEE HAS ITS WORK CUT OUT FOR IT. THE PRESIDENT'S REQUEST CALLS FOR DEEP CUTS TO NASA'S BUDGET OVER THE NEXT FIVE YEARS, AND IN THE COMING MONTHS CONGRESS MAY CUT SPENDING ON ALL GOVERNMENT PROGRAMS--INCLUDING NASA--EVEN MORE THAN THE PRESIDENT HAS.

IF WE ARE UNABLE TO FIND ADDITIONAL MONEY FOR NASA, IT MAY NOT BE POSSIBLE TO DO ALL THE THINGS WE WOULD LIKE TO DO IN THE SPACE PROGRAM. IT MAY NOT BE POSSIBLE TO START NEW PROGRAMS AS SOON AS WE WOULD LIKE. AND SOME VERY GOOD PEOPLE MAY LOSE THEIR JOBS. IN SHORT, WE ARE FACING SOME VERY TOUGH TIMES.

I KNOW THAT NASA AND THE CONTRACTORS HAVE ALREADY DONE SOME CUTTING BACK, AND THAT MORE CUTS ARE PLANNED. I THINK THAT IS A SENSIBLE RESPONSE. HOWEVER, AS WE CONSIDER WHAT TO DO, I THINK WE NEED TO KEEP TWO PRINCIPLES IN MIND:

FIRST, LET'S NOT MAKE "PENNYWISE AND POUND FOOLISH" CUTS. THE NATION'S TAXPAYERS HAVE INVESTED SIGNIFICANT RESOURCES OVER THE LAST THIRTY SIX YEARS TO MAKE THE UNITED STATES PREEMINANT IN SPACE. WE SHOULD NOT JEOPARDIZE THE FRUITS OF THAT INVESTMENT IN A SHORT-SIGHTED ATTEMPT TO SAVE MONEY. WE NEED TO CUT BACK WHERE WE CAN, BUT CONTINUE TO INVEST WHERE WE MUST.

SECOND, WE HAVE TO AVOID THE TEMPTATION TO TAKE CREDIT FOR SAVINGS BEFORE THEY ARE REALIZED. I KNOW THAT NASA WOULD LIKE TO

KEEP ALL ITS EXISTING PROGRAMS AND EVEN ADD A NUMBER OF NEW ONES IN THE FY 1996 BUDGET. IT'S GOING TO TRY TO DO THAT BY "FUNDAMENTALLY RESTRUCTURING NASA". I THINK I SPEAK FOR ALL MEMBERS WHEN I SAY THAT WE WANT TO WORK WITH NASA TO MAKE THE AGENCY MORE EFFICIENT AND ELIMINATE WASTE. AND I TRUST THAT THE LEADERSHIP OF NASA WILL CONSULT WITH CONGRESS AS NASA DRAWS UP ITS PROPOSALS.

BUT IT TAKES TIME--YEARS IN FACT--TO RESTRUCTURE AN AGENCY THOUGHTFULLY AND FAIRLY. AND NASA WILL BE FACING SIGNIFICANT FUNDING SHORTFALLS BY FY 97 IF NOT SOONER. SO I THINK THAT THIS SUBCOMMITTEE WILL HAVE TO TAKE A SERIOUS LOOK AT ALL THE PROPOSED NEW STARTS TO SEE WHETHER THE MONEY WILL BE THERE TO PAY FOR THEM IN THE YEARS AHEAD. IF ITS NOT, THEN WE MAY HAVE TO DELAY OR ELIMINATE SOME OF THOSE NEW STARTS.

I LOOK FORWARD TO THE TESTIMONY OF ALL OF OUR WITNESSES TODAY.

Mr. SENSENBRENNER. Today we have a panel of three witnesses, Mr. Daniel Goldin, Administrator of NASA; Mr. Frank Weaver, Director of Commercial Space Transportation in the Department of Transportation, and Mr. Keith Calhoun-Senghor, Director of the Office of Air and Space Communication in the Department of Commerce.

Without objection, the complete written statements of all three of the witnesses will be included in the record immediately following each of their remarks. I would like to ask each of the witnesses to confine their oral remarks to a liberal five minutes so that members of the subcommittee will have ample time to ask questions. So without any further ado, Mr. Goldin, you are the leadoff witness.

STATEMENT OF DANIEL S. GOLDIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C.

Mr. GOLDIN. Thank you, Mr. Chairman. I would like to start off by telling the committee how proud I am of the NASA team. This team has done unbelievable work, not just technically, but in the management sense. I think the Shuttle Mir Mission, which we just concluded, is a perfect example of this outstanding team. They were able to adapt in real time in space and make things happen.

They were able to work across the ocean with our international partners. They did what they said they were going to do, and when that shuttle landed, I have to admit to this team, I had tears in my eyes thinking about what a wonderful, wonderful thing we have.

On the space station. In this last year—last year, we told you the space station would cost $17.4 billion and have the first element launched November 1997. I sit before you to say today, one year later, we have $15.3 billion to go and we will launch on November '97. We negotiated tough hard contracts with our prime contractor and with the Russians.

The Hubble rescue, we did it. We fixed the GOES spacecraft and America has a reliable advanced weather satellite. Over the last two years, we cut the budget by 30 percent and last year at this time we were asked by this subcommittee, would you be able to reprogram money for science? We spent the whole summer working on this and I am proud to say that we have reprogrammed $1.6 billion for science.

The fiscal 1996 budget request is robust. It does the right things in stations, shuttle, aeroscience and technology. We are revolutionizing the way we do new spacecraft with the New Millennium Program, which we are coordinating throughout the U.S. Government. It is going to change completely how we look at spacecraft. We are looking for an order of magnitude reduction in cost and weight. We are starting the X-33 and the X-34 programs. At NASA we will not have an approach called LIFO, last in, first out. Everything is on the table.

I want to clarify, with the changes we are looking at, we are only doing analysis. It is only since January 19th that we knew about these budget cuts. All we ask the committee to do is to work with us as we do the analysis. We are going to attempt to take the major cuts out of infrastructure. By mid May, early June, we will have the analysis done. At that time, if we cannot take it out of infrastructure, we are going to come forward and we will tell you which programs have to be cut.

So I want you to understand, we are not trying to play this loose. We want to have time to do the analysis and we want to work with you.

The American people spoke in November 1994 and they wanted less government and more results. I think we have an obligation to look at the infrastructure. We are faced with three choices. We could take the easy way out and just cut programs and have a hollow institution with an infrastructure that was designed in the 1950s and '60s. We could cut an enterprise and have an incomplete agency, or we could face the real hard decision that many people in Congress have been asking NASA to undertake.

It is not going to be easy. There are people's lives and careers at stake, and this is going to be difficult, but if we don't step up to it now, we will have lost an opportunity. If we just choose to cancel a program and maintain the infrastructure because it is too hard or too worried about upsetting the apple cart, we will have made the wrong decision.

Let me tell you why we have to look at the infrastructure. NASA was set up in the '50s and '60s. We didn't have a digital information system. We didn't have a digital revolution, so each center was set up as a self-contained unit. Every center had full capacity to do everything and they didn't have any intercommunications.

The budget battles of the '70s and '80s caused each of the NASA centers to do the same things that the other centers were doing. They pulled work in-house and we went to nonobjective contracting. A lion's share of the work that NASA does is nonobjective contracting with service support contractors at our centers.

We ought to be spending the money with industry to enable industry, not to direct it. This is going to be very, very difficult for some of our major supporters because it is going to shift jobs out of the NASA centers into the commercial industry. Very difficult. It is going to cause us to drastically cut the number of people in the NASA work force.

Finally, I say we are on the right path. We are about the future. We ought to have the courage to do the analysis and we intend to do just that. I ask the committee for support of an orderly process.

Mr. Chairman, you are absolutely correct. Safety is paramount. This process has called for a stable budget in 1995 and 1996 so we don't do precipitous things with the space station, so we don't do precipitous things with our work force. These are great Americans and they deserve dignity and respect and we shouldn't suddenly discard them so we take the time to plan it right. The budget calls for the significant reductions to start in fiscal 1997 and beyond.

So I want to close by saying, I thank President Clinton for his leadership and vision for America's space program. I am excited about the possibilities. When we complete the studies, we will have a NASA program that assures economic opportunity, national security, and inspiration for a Nation that so deserves it. Thank you very much.

[The prepared statement of Mr. Goldin follows:]

Hold for Release Until
Presented by Witness

National Aeronautics and
Space Administration

February 13, 1995

Subcommittee on Space and Aeronautics

Committee on Science

House of Representatives

Statement by:
Daniel S. Goldin
Administrator

104th Congress

Statement of
Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Space and Aeronautics
Committee on Science
House of Representatives

February 13, 1995

NASA is an investment in America's future.

We do what no other part of government can do. We boldly expand frontiers in air and space to benefit the quality of life on Earth. We seek to unravel the mysteries of the universe and, in the process, we make the country stronger and more competitive.

The FY 1996 budget request of $14.26 billion will allow us to continue to fulfill that promise (Figure 1). We will deliver a strong aeronautics and space program that's relevant to America.

That's the good news.

The tough news is that we will make **fundamental changes** at NASA to absorb future cuts.

We've already cut our five-year budget plan by 30% since 1993. We've already reduced our support contracts and downsized our workforce. We've already eliminated low-priority programs. Given all that, the need to find an additional $5 billion calls for sweeping changes at NASA. We must rethink the entire Agency (Figure 2 & 3).

Make no mistake. When this is over, NASA will be profoundly different. We're going to restructure the Agency. But the NASA that emerges will be better than ever.

We have a vision for NASA, and a road map for change.

First and foremost, we're going to revolutionize the structure of NASA. Our workforce. Our relationship with our contractors. Our facilities. In a word, everything.

In the past, one of the ways we've dealt with cuts is to trim NASA's structure. Trimming won't do it anymore. The Agency must be completely restructured. The new NASA will be fundamentally different from the old.

We're going to use seven basic principles to restructure:

- One, we'll cut out duplication and overlaps and consolidate.
- Two, if we don't have to do it ourselves, we won't. Maybe a university or the private sector should be doing a function NASA's doing now. We'll turn it over to them.
- Three, we'll change the way we work with prime contractors. We'll do less. They'll do more.
- Four, we'll privatize and commercialize wherever appropriate. We'll work with industry on the front end and then get out of the way. That's exactly what we're going to do with the Reusable Launch Vehicle Technology Program.
- Five, we'll work to get regulations changed so we can do business differently and empower the Agency to work more efficiently and effectively with contractors.
- Six, we'll cut way back on NASA's ever growing operations budget by turning these activities over to the private sector, and return NASA to the cutting edge of research and development.
- Seven, we will emphasize objective contracting. This is a critical procurement reform. Contractors will be given a statement of work that calls for a specific product that's deliverable to NASA by a firm deadline. We want NASA to enable the aerospace business, not to direct it. Objective contracting enables companies to align their commercial aerospace business with their NASA-related work. This may require policy and regulatory changes discussed above.

Using these principles, we want to make the full $5 billion reduction through restructuring. Cutting our workforce, cutting on-site contractors, cutting facilities. This will be painful. It means NASA employees will lose their jobs. Contractors working at NASA, and at their own offices, will lose their jobs (Figure 4).

I wish we could reinvent NASA without any disruption to any employee. I wish it were easy. But it isn't. We are offering a second buyout, which should help move us toward our targets. We hope to make all of the cuts through restructuring. If our analysis shows we can't, then and only then will we cancel programs.

But I do want to emphasize an important change that affects our programs. The way we're evaluating them now is profoundly different from how we've done it in the past. We used to measure the Agency's vitality by the level of its budget. Not any more. We're going to measure our success by output, not input. We'll judge our success by the science, the R&D, the **results** of what we do, not by the dollars going in.

The kind of sweeping changes this budget calls for are new. But doing things more efficiently and effectively with less money is not at all new at NASA. We already have begun a revolution. We have been in the vanguard of the President's and Vice President's reinvention challenge.

The White House recently announced a second phase of the National Performance Review to examine the basic missions of government. We're already doing that. We're in the middle of a top-to-bottom review of the Agency to determine where to cut. We're looking at everything we do. Everything is on the table.

- In October, we began a zero base review of our civil servants and contractors.
- Two teams are reviewing Shuttle operations. One began last September and the other last month. They're looking for ways to significantly cut costs while achieving safety equal to or better than today's level. Safety governs everything we do. It's our top priority.
- We're involved in the Federal Lab Review, to see how our R&D labs can be more efficient and effective. This review began in September.

We'll also make NASA less of an operations Agency and more of an R&D Agency. This process begins in FY 1996. Let me turn now to some of the specifics of the FY 1996 budget:

- We intend to maintain our critical major activities.
- We're continuing the "better, faster cheaper" revolution (Figure 5). We're replacing large, complex spacecraft with smaller, less expensive missions with shorter development times:
    - Mars/Pathfinder,
    - Near Earth Asteroid Rendezvous,
    - Mars Surveyor,
    - Explorer missions, and
    - Smallsat program (Lewis and Clark missions).
- Our Mission to Planet Earth program has made progress in understanding the global environment. We have found a way to measure sea level change from space. We have an objective way of measuring global temperature change from space. Our airplanes are studying the last unpolluted air mass on Earth. This air mass, which is over the central Pacific Ocean, is relatively untouched by human activity. This information will give us a yardstick by which to measure the effects of an industrial world on the atmosphere. And there's much more to come. The Earth Observing System (EOS) will make the first integrated observations of the climate beginning in 1998. EOS results will help scientists create advanced computer models of the interactions between air, land, water and life. These results will also be made available to farmers, foresters, fishermen, resource planners, educators, and the public. Furthermore, we hope these efforts will spur the growth of a whole new remote sensing industry and give U.S. businesses a competitive edge in the expanding world-wide remote sensing market.
- We're continuing to work to improve Shuttle safety. Safety is our highest priority. With the goal of enhancing overall safety, this budget includes funds for modifications to the Main Engine, Orbiter and Redesigned Solid Rocket Booster. The Shuttle continues to perform brilliantly. The rendezvous with the Mir earlier this month was a dazzling feat. The docking mission planned for May will be a technological miracle and a powerful symbol of the new cooperation between the U.S. and Russia.

- We'll continue to move ahead with vital aeronautics programs, like the High Speed Research Program. This is cutting-edge technology. It has the potential to create 150,000 jobs and $250 billion in revenue.

- We're also moving full speed ahead with the Advanced Subsonic Transport program. We'll be working with industry to develop high-payoff technologies that support a safe, environmentally friendly, highly productive global air transportation system. In FY 1996, we've redirected some resources to emphasize two areas our customers say are critical — air traffic management technologies and affordable design and manufacturing.

- We're continuing our exciting work in the High Performance Computing and Communications Program. Today's supercomputers can do between 10 and 100 billion calculations a second. Our goal is one trillion in the next few years, and a quadrillion in the next 15. Industry will take this technology and run with it.

- Just as we promised last year, we're increasing space science funding (Figure 6). We'll be starting some exciting new science programs:

    - We're staging a revolution with the New Millennium spacecraft. There's no other word for it. This is a brand new era in spacecraft design. These small, agile spacecraft will be built on a bench, not in a high bay area. They'll be about a tenth of the cost and about a tenth of the weight of today's spacecraft but with the same high quality science. They're like nothing that's ever been done before.

    - We're starting a new era in infrared astronomy with The Stratospheric Observatory for Infrared Astronomy (SOFIA), and The Space Infrared Telescope Facility (SIRTF). We hope to reveal the answers to outstanding questions about planetary disks, brown dwarfs, and the most luminous galaxies.

    - More Discovery missions -- we'll do one a year, insuring that university scientists *and their students* are on a fast-track to knowledge about our Solar System.

    - And we'll do the Rosetta mission. This is an example of how we're doing business differently at NASA. Through international cooperation, we'll do this mission for much less than the original comet rendezvous we'd planned. ESA is taking the lead. We'll rendezvous with a comet and deliver landers to the surface. One lander will be American, developed with French participation. And one will be German.

- This budget request also lays the groundwork for the next 20 years in space exploration. We'll be developing the tools of the future.
    - I've already mentioned the New Millennium spacecraft. It's one of the most exciting ways we're preparing for the future.
    - The Reusable Launch Vehicle Technology Program is another ground breaker. The Shuttle is a magnificent and versatile spacecraft. But it's time to look to the next era in space. Reusable Launch Vehicles should make access to space affordable and open up the space frontier to industry and entrepreneurs.

And the way we're working with industry is the wave of the future. We're going to work with industry to resolve high-risk development issues and then get out of the way. Industry will build and operate the launch vehicles. In the future, I expect that NASA will be just another customer for commercial launch services.

These are some of the highlights of our FY 1996 budget. We have a strong program that builds on the spectacular successes of this past year.

We had a record year in FY 1994, with tremendous successes in three areas: we continued to transform the way NASA operates; we performed stellar missions; and we responded to Congressional direction to increase funding for space science.

Let me start with the first area. We continued to revolutionize NASA:

- We responded to specific recommendations to the Agency from the National Performance Review. These recommendations varied from improving our technology transfer to making program management more effective.
- We implemented an award fee initiative that builds in cost controls and holds contractors accountable for performance.
- We dramatically simplified our process for selecting and awarding contracts of under half a million dollars a year.

- In partnership with contractors, we started an initiative to improve cost control. We set up another process to simplify and enhance major procurement selection.

- We completely changed the structure of the international Space Station program and streamlined its management. This is a model for our new way of doing business. We overhauled the Station from top to bottom. We selected a single prime contractor, Boeing, and we now have a signed contract. We established a single program office at the NASA Johnson Space Center. We built in real incentives for cost and technical performance and real penalties for delays.

Now let me turn to the second area -- our outstanding program accomplishments in 1994.

- I mentioned the Station management. We also built 26,500 pounds of hardware. Thanks to stable funding, we are building the Station. We're not debating it anymore. We're doing it. Further, we solidified Russian participation and signed a $400 million contract for Russian space hardware, services and data. The Station is right on track.

- The Shuttle program also was another incredible success. It accomplished seven highly productive science and technology missions in 1994. The first Russian cosmonaut flew aboard a U.S. spacecraft as we continued to prepare for visits to the Mir. All together, the Shuttle carried 42 astronauts to space, including crew members from Russia, Japan and the European Space Agency. They spent over 81 days in orbit.

- We did absolutely outstanding science last year:

  - For the first time ever, scientists now have decisive evidence of the existence of black holes, courtesy of the Hubble Space Telescope. Shortly after being repaired last December, Hubble was trained on the giant elliptical galaxy M87, located 50 million light years away in the constellation Virgo. Hubble's observation confirms more than two centuries of theory and conjecture about the reality of black holes.

- Hubble data confirmed the existence of protoplanetary disks around newborn stars. This is the strongest evidence yet that the same process that formed the planets in our Solar System is common throughout the galaxy and, presumably, the universe.

- After peering deep into space and far back in time, Hubble detected primordial helium in the early universe. This is important because it confirms one of the critical tenets of the Big Bang theory. It is one more important confirmation of our best guess as to how space and time formed.

- This year, a strange new phenomenon known as upper atmospheric flashes was recorded for the first time. The Compton Gamma Ray Observatory contributed to this discovery. These flashes last only a few hundredths or thousandths of a second, and extend upward as high as 60 miles. Some reach through the ozone layer to the ionosphere. It is thought that these flashes provide a link between Earth's lower atmosphere to events in the upper layers of our atmosphere.

- The impact of Comet P/Shoemaker-Levy 9 with Jupiter in July was a seminal event for astronomers. Not only was the Near Earth Object Program able to detect the comet in 1993 and predict its eventual impact -- to the day -- but it also afforded an unprecedented campaign to observe this event from ground-based and space-based observatories. The observations acquired revealing data about the composition of comets and the composition of the Jovian atmosphere. The event itself was the subject of worldwide interest from the scientific community and the public.

- The Galileo probe, enroute to Jupiter, confirmed that a tiny moonlet orbits the asteroid Ida. That moonlet was recently named Dactyl. The size of the asteroid Ida suggests that such moons may be more widespread than previously thought.

- In April, NASA successfully launched the next-generation Geostationary Operational Environmental Satellite, GOES-8. The new weather satellite will enable forecasters to more accurately track and predict storms, including hurricanes. As the capabilities of the new satellite become operational, television viewers around the country will notice sharper and more detailed images on their local weather forecasts.

- Last year, NASA demonstrated two new techniques for observing the Earth from space. In April, and again in October, NASA flew a multi-frequency, multi-polarization radar, the most complex ever flown in space, to study ecology, water cycles, vegetation cover, oceanography, geology and volcanology. This was the first remote sensing observation of the Central African habitat of mountain gorillas, in an area now threatened by civil unrest in Rwanda. The second technique was demonstrated last week aboard the Space Shuttle. Known as lidar, for light detection and ranging, scientists used a laser beam to bounce off objects and used the reflected energy to make environmental observations of the planet.

- Mission To Planet Earth is delivering more science every year. Results from our upper atmospheric research satellite indicate that ozone depletion is stabilizing -- the first sign the treaties are working. Topex/Poseidon made the first global measurements of sea level rise in 1994, and saw El Nino weather events in the making. Soon, we'll be able to predict rainy winters like the one California is having.

- We also delivered on our commitment to Congress to increase funding for NASA's Space Science program by reallocating funds (Figure 7).

We clearly had some stunning successes last year. And we will in the future. A new, restructured NASA will continue to strengthen the country and inspire America's children.

We're an investment in the future.

Twenty years from now, America will have recaptured a portion of the 25% market share in aviation the nation has lost over the last 25 years. We'll have a domestic aviation industry second to none. It will produce a wide range of highly competitive products that are quiet, environmentally compatible and sustain hundreds of thousands of high-quality manufacturing jobs.

We will have mapped the entire Solar System. We will have gone past Pluto and out to the Oort cloud, where the building blocks of creation are hidden.

We will have sent an armada of small spacecraft out into the Solar System. And the information they send back will belong to everyone. Students, workers, older Americans -- everyone -- will take part in these discoveries.

We'll take high-resolution pictures of planets — if they exist — within 30 to 50 light years of Earth. Wouldn't it be exciting if we found a blue planet with clouds, with carbon dioxide and oxygen out of equilibrium.

Children in science classes will operate robots on the Moon. High school students will analyze samples and put their results on the Internet.

We will restore people's link to nature through Earth observations and communications. We will understand much more about our own planet and global environment through Mission to Planet Earth.

While we learn how people can live and work in space, we will contribute to improving the quality of health care for old and young alike. Doctors will have enhanced data and new techniques. The combination of the unique research we do in space and the medical research done on the ground by NIH and others will be a powerful force for unlocking the mysteries of disease.

The possibilities for what we will have learned from the Station are incredible. We may have learned how people can live and work in space for long periods of time. We may have learned what we need to know to send humans to another planet. We will be planning the world's next destination in space.

All of these things are possible if we continue to revolutionize NASA. A strong, dynamic space and aeronautics program is an investment in America's children and the nation's future.

I want to close by thanking the President for his leadership. He's given us clear, forceful direction. He's asking us to do what's most important to Americans and do it for less money. In fact, he's asking us to change NASA as we know it.

I know there are many members of Congress who support that. They've told us much the same thing. To deliver a relevant program for less. And to overhaul the Agency to make that happen. And with your help, that's exactly what we're going to do.

And we do need your help to accomplish all this. The massive restructuring I have described will not be quick or easy. This is an undertaking that goes to the basics of the Agency's structure, and what we do will forever change NASA. The roles and missions of our Centers and Headquarters will change. Our workforce, our contractors, our facilities will change. It will take time, careful study and constant vigilance to maintain safety of flight and deliver on our program commitments while we do this.

NASA is a very special Agency. We must fly the Shuttle and do all of our missions safely. We need a controlled process for change that enables us to retain a critical balance of skills at NASA. Without that balance, we will not be able to make safety equal to or better than today's level. We also need a controlled, deliberate process in order to protect the human dignity of our employees. They need time to transition to new jobs. These are brilliant people — many of whom have left their mark not just on NASA but on the country. Further, as we phase out some of our activities, we will be exploring the possibility of turning them over to local communities. That could be good news for these areas because it may mean new jobs and industries, but this, too, will take careful planning if the process is to work smoothly.

We will need time to do all this right. We will also need the strong support of Congress and an appropriation at the level of the President's FY 1996 budget request -- $14.26 billion. The President's FY 1996 budget request enables us to deliver on our promise to you and to the Nation to deliver a vital program that helps position America for a successful, competitive 21st Century.

The stability of this funding level -- both our current FY 1995 level and the President's FY 1996 budget request -- is essential. In addition to enabling us to preserve or enhance safety and protect the dignity of our employees, we'll need this funding to make the dramatic changes I've described. Moving employees, achieving new automation and many other aspects of restructuring cost money. These are one-time investments that will yield savings in the long run, but they do require upfront expenditures. While we will achieve some savings from our second buyout, this money will be needed for the cost of achieving the new, transformed NASA.

We plan to work very closely with the distinguished Members of this Subcommittee and others in Congress. We intend to be a "user-friendly" Agency for Congress. I'm confident that, working together for the good of the Agency and the good of the country, we will continue the revolution that's already begun at NASA.

Thank you.

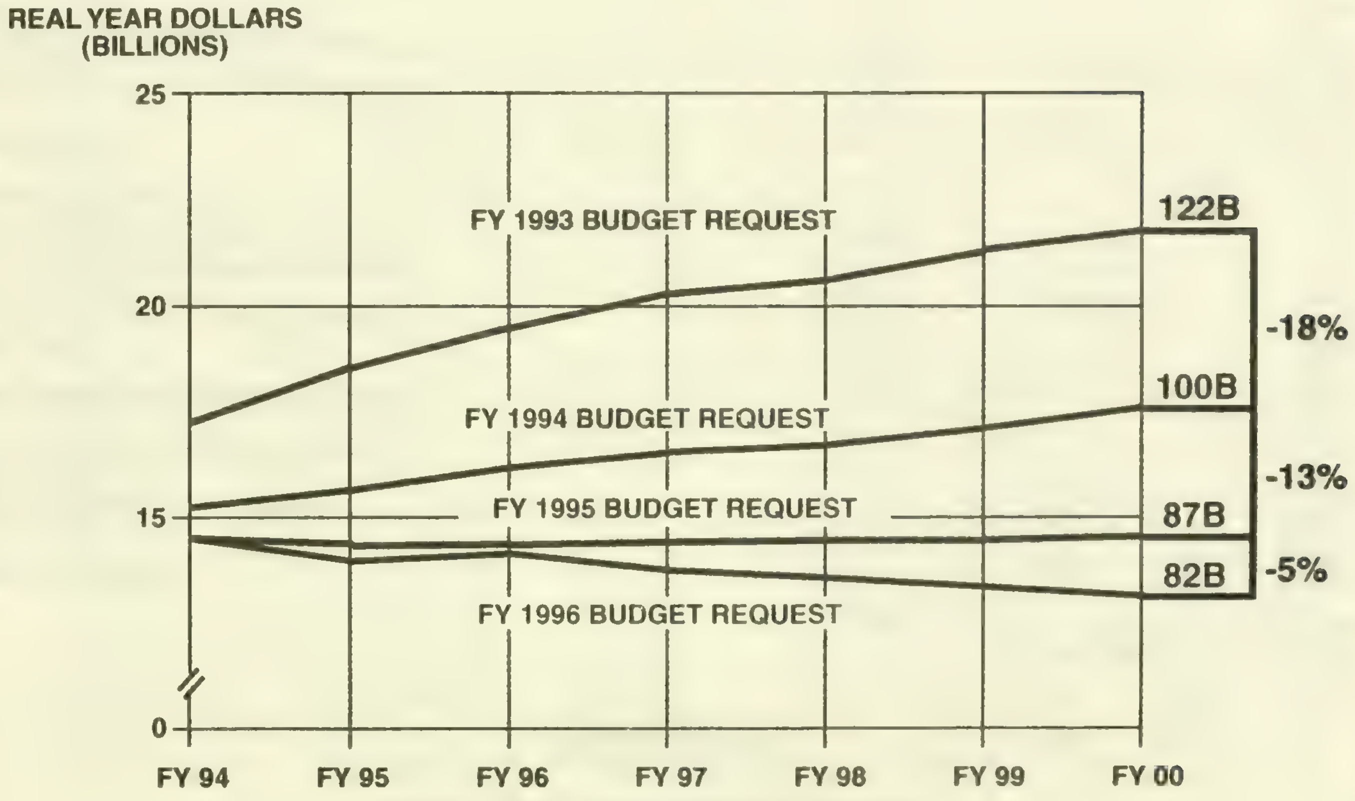
NATIONAL AERONAUTICS & SPACE ADMINISTRATION

FY 1996 BUDGET SUMMARY
(MILLIONS OF DOLLARS)

		BUDGET PLAN	
	1994	1995	1996
HUMAN SPACE FLIGHT	**6,074.3**	**5,514.9**	**5,509.6**
SPACE STATION	1,939.2	1,889.6	1,833.6
US/RUSSIAN COOPERATIVE PROGRAM	170.8	150.1	129.2
SPACE SHUTTLE	3,558.7	3,155.1	3,231.8
PAYLOAD AND UTILIZATION OPERATIONS	405.6	320.1	315.0
SCIENCE, AERONAUTICS AND TECHNOLOGY	**5,792.5**	**5,943.6**	**6,006.9**
SPACE SCIENCE	1,920.9	2,012.6	1,958.9
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	507.5	483.1	504.0
MISSION TO PLANET EARTH	1,068.0	1,340.1	1,341.1
AERONAUTICAL RESEARCH AND TECHNOLOGY	1,067.2	882.0	917.3
SPACE ACCESS AND TECHNOLOGY	562.4	642.4	705.6
MISSION COMMUNICATION SERVICES	581.0	481.2	461.3
ACADEMIC PROGRAMS	85.5	102.2	118.7
MISSION SUPPORT	**2,667.4**	**2,589.2**	**2,726.2**
SAFETY, RELIABILITY AND QUALITY ASSURANCE	34.3	38.7	37.6
SPACE COMMUNICATION SERVICES	248.2	226.5	319.4
RESEARCH AND PROGRAM MANAGEMENT	2,175.6	2,189.0	2,202.8
CONSTRUCTION OF FACILITIES	209.3	135.0	166.4
INSPECTOR GENERAL	**14.7**	**16.0**	**17.3**
NATIONAL AERONAUTICAL FACILITIES		**400.0**	
TOTAL BUDGET AUTHORITY	**14,548.9**	**14,463.7**	**14,260.0**
TOTAL OUTLAYS	**13,693.3**	**14,239.4**	**14,125.3**

(FIGURE 1)

FY 1996 PRESIDENT'S BUDGET



(FIGURE 2)

FY 1996 PRESIDENT'S BUDGET
MILLIONS OF DOLLARS

HUMAN SPACE FLIGHT, SCIENCE, AERONAUTICS AND TECHNOLOGY, MISSION SUPPORT, AND INSPECTOR GENERAL APPROPRIATIONS

	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
FY 1995 BUDGET REQUEST	14,551	14,300	14,400	14,500	14,600	14,600	14,700
CHANGE	-3	-236	-140	-604	-947	-1,189	-1,532
FY 1996 BUDGET REQUEST	14,549	14,064	14,260	13,896	13,653	13,411	13,168

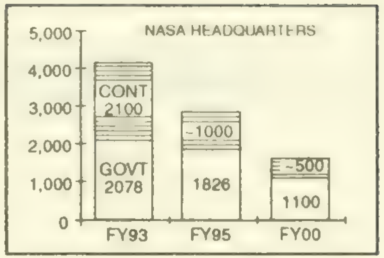
NATIONAL AERONAUTICAL FACILITIES APPROPRIATION

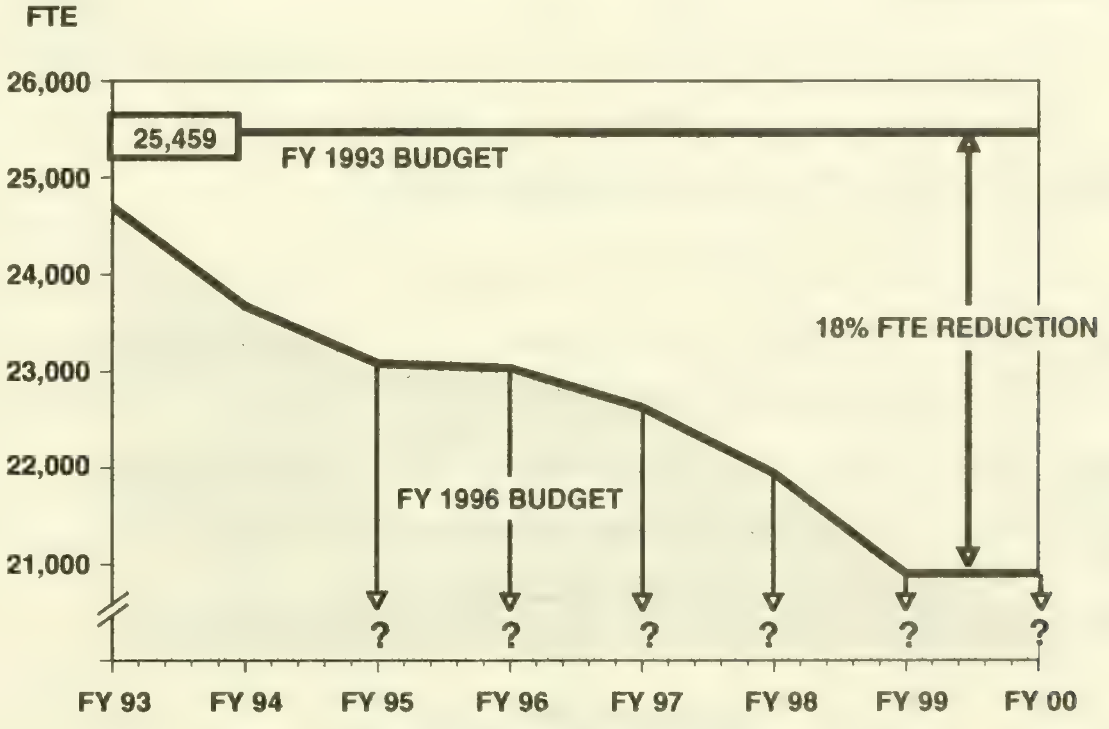
	FY 1995
FY 1995 BUDGET REQUEST	---
CHANGE	400
FY 1996 BUDGET REQUEST	400 *

*Legislation is being proposed to extend availability of these funds from July 15, 1995 until September 30, 1997.

(FIGURE 3)

TOTAL CIVIL SERVICE EMPLOYMENT



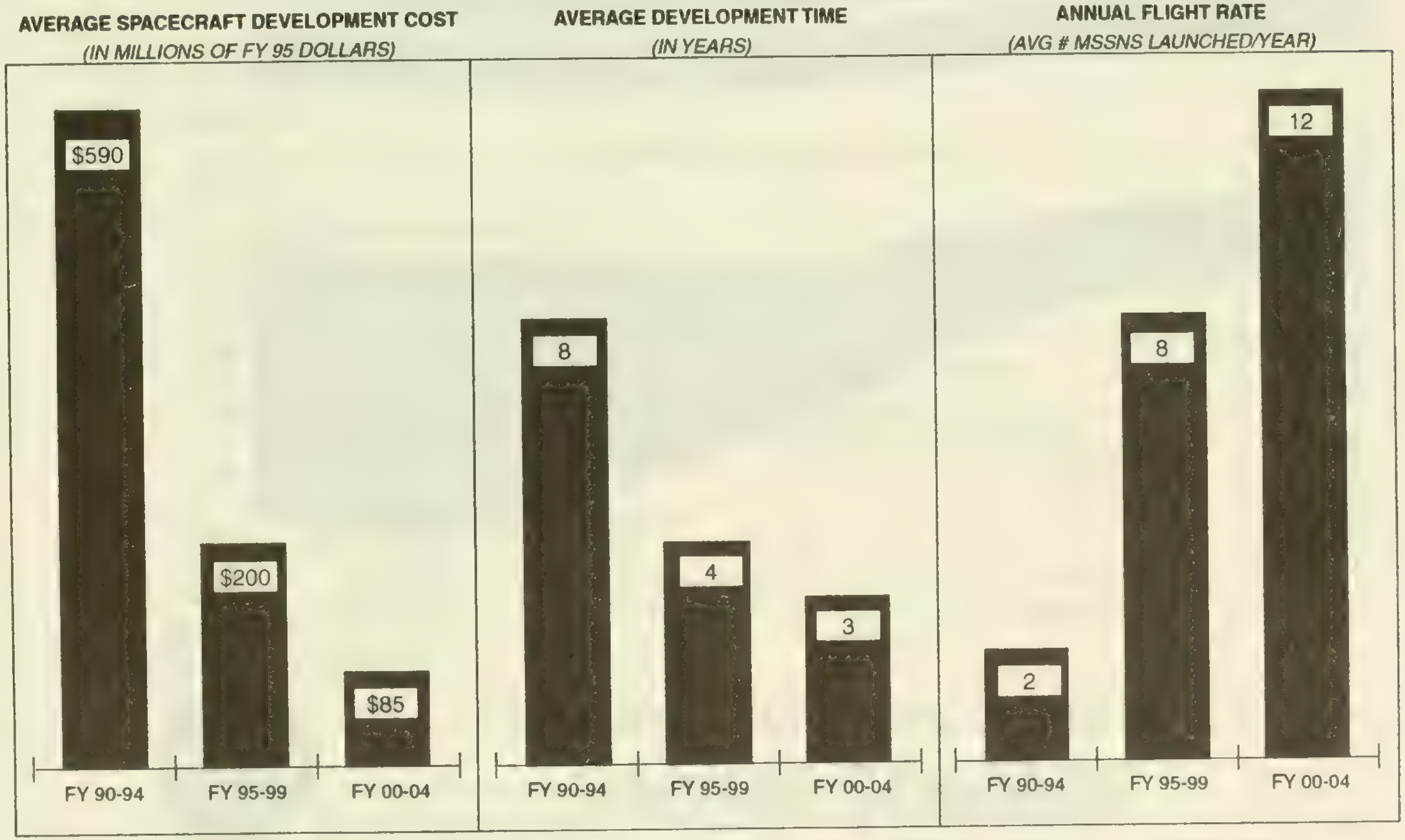


DOES NOT REFLECT THE BUYOUT

(FIGURE 4)

FASTER, BETTER, CHEAPER

NASA SPACE SCIENCE AND MISSION TO PLANET EARTH PAYLOADS

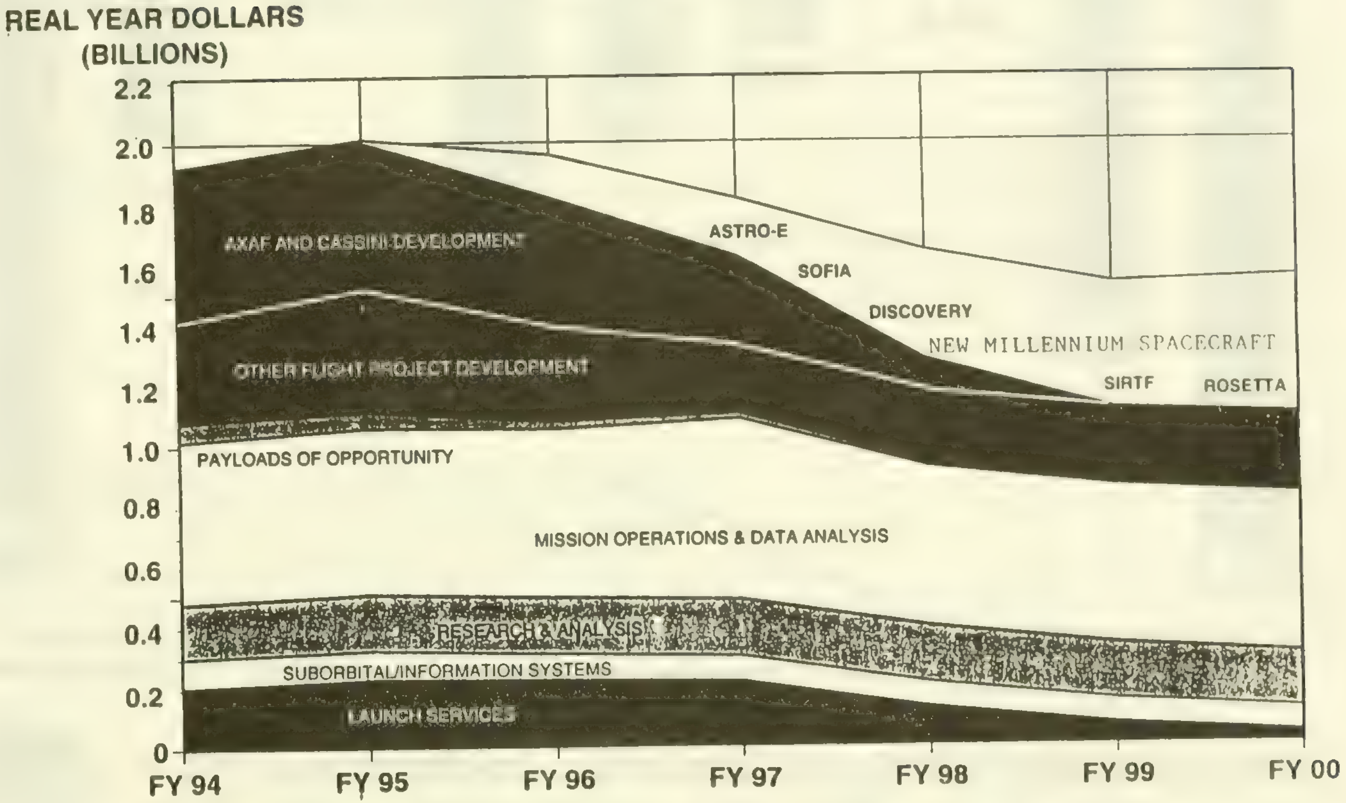


CONSISTENT WITH AN OPERATING SPACE STATION AND A TOTAL AGENCY BUDGET OF ~$13 BILLION

(FIGURE 5)

SPACE SCIENCE

FY 1996 PRESIDENT'S BUDGET

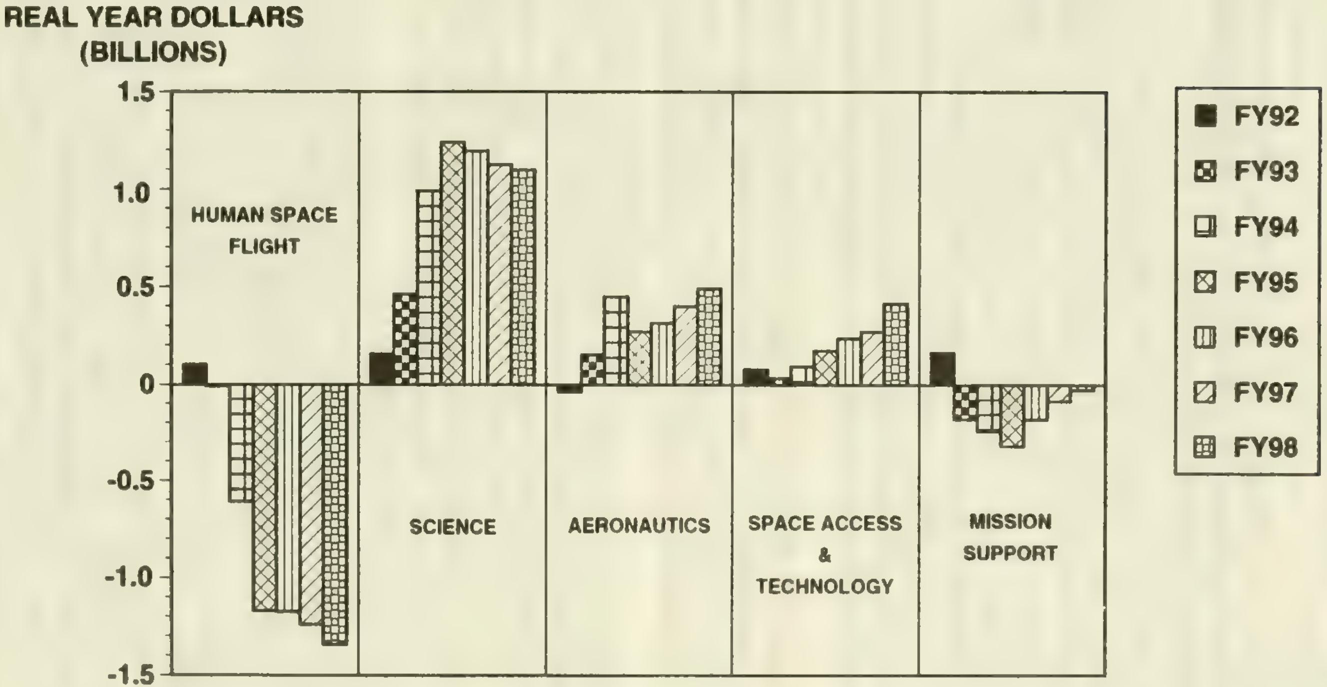


THE ABOVE INFORMATION DOES NOT REFLECT THE UNRESOLVED PERCENTAGE REDUCTION DIRECTED BY THE ADMINISTRATION

(FIGURE 6)

FY 1996 PRESIDENT'S BUDGET

CHANGES FROM FY 1991



THE ABOVE INFORMATION DOES NOT REFLECT THE UNRESOLVED PERCENTAGE REDUCTION DIRECTED BY THE ADMINISTRATION

(FIGURE 7)

Mr. SENSENBRENNER. Thank you Mr. Goldin.
Mr. Weaver.

STATEMENT OF FRANK C. WEAVER, DIRECTOR OF COMMERCIAL SPACE TRANSPORTATION, DEPARTMENT OF TRANSPORTATION, WASHINGTON, D.C.

Mr. WEAVER. Let me begin by thanking you, Mr. Chairman, and the Members for the opportunity to address the subcommittee today on our fiscal 1996 budget. On behalf of Secretary Peña, we at the Department of Transportation and the Office of Commercial Space Transportation look forward to working with all of you to shape our Nation's future in commercial space.

This is a challenging period in the commercial space industry. In 1984, when the Commercial Space Launch Act established my office, the U.S. was the dominant supplier in the world space launch market.

At the end of 1994, 10 years later, Europe's Arianespace is the dominant supplier. To reverse this trend, we have established a goal to try to restore the U.S. launch industry as the leading supplier of commercial launch services in the international marketplace.

The authority and function of the Office of Commercial Space Transportation to meet this goal is twofold. First, for the Commercial Space Launch Act, we regulate the U.S. space transportation industry to protect the public's safety. Our second mission, for the national space transportation policy, signed by President Clinton in August of 1994, was to enhance the international competitiveness of the U.S. space launch industry.

We, along with the Department of Commerce, are to develop public-private sector partnerships to cooperate with NASA and the Department of Defense in the development of new launch systems and infrastructure. To fulfill our goal, the Office of Commercial Space Transportation is requesting a total of $6.541 million in fiscal year 1996. In this is only an increase of $497,000 over the enacted fiscal year 1995 budget. While five additional positions were authorized in fiscal year 1995, they could not be funded until fiscal year 1996.

Allow me, Mr. Chairman, and members of the committee, to just mention a few of the activities that the Department of Transportation is undertaking during 1995 to help achieve this vision of commercial space in the next two decades.

The first activity is in the area of launch vehicle and site regulations. The Department of Transportation is updating regulations concerning commercial launches and the operation of commercial launch sites to encompass new space transportation systems that have been developed since then.

The second activity is in the area of international trade and space launches. The Office of Commercial Space Transportation leads the interagency working group on information, which is responsible for monitoring compliance of China and Russia with the trade agreements that have been negotiated.

We also support the U.S. Trade Representative by conducting assessments of satellite markets in geostationary and low earth orbit that enable the U.S. Trade Representative to allow foreign launch suppliers to participate without disrupting the market.

The third area of concern is in vehicle technology. The Department of Transportation chairs the Committee on Transportation Research and Development of the National Science and Technology Council, and I chair the Space Launch Working Group, comprised of the Department of Defense, NASA, Department of Commerce, Department of Energy, and DOT to coordinate vehicle research and development. We also work to develop a common set of space lift requirements to serve the needs of the civil, commercial, and national security areas.

The fourth activity is in the area of space launch infrastructure. We are working closely with the U.S. private sector, existing Department of Defense and NASA launch sites, emerging non-Federal spaceports in California, Florida, New Mexico and Alaska and interested State governments to develop capabilities to support a variety of launch vehicle options.

I would now like to share my vision of the future with you. Commercial space is a growing industry with several new satellite services on the horizon. Today's satellite communication market is about $6.5 billion internationally with $580 million representing revenue to the U.S. space launch industry.

By the turn of the century, global mobile communications, satellite systems and services will represent a $20 billion market of which $11 billion of that will be for the provision of satellites, launches and ground equipment.

The leadership position that the United States currently enjoys in providing these satellites and services will also require that the United States have a reliable and cost-effective launch capability. Until the evolved expendable launch vehicle family becomes operational around the turn of the century, upgrades to the traditional expendable launch vehicles are essential in order to stay competitive.

We believe firmly that the reusable launch vehicle, such as the single-stage-to-orbit concept, is a promising technology to bring about a reduction in the cost to reach space. All of these new and nonconventional space systems, technologies, and the emerging commercial spaceports pose new and unique safety and regulatory issues.

The Department of Transportation is already conducting prelicense consultations with the companies developing these systems and facilities to advise them on approaches to safety issues and other requirements for vehicle design, operation, and maintenance.

Finally, Mr. Chairman, as part of the President's Reinventing Government initiative, we and all Federal agencies are reexamining our mission. We are seeking customer input as we ask whether the mission could be accomplished without Federal investment, what the benefits of competition are, and ways to cut red tape and empower employees. This concludes my remarks.

Once again, I thank you for the opportunity to appear before you this afternoon and I would be happy to answer any of your questions.

[The prepared statement of Mr. Weaver follows:]

STATEMENT

OF

FRANK C. WEAVER
DIRECTOR
OFFICE OF COMMERCIAL SPACE TRANSPORTATION
U.S. DEPARTMENT OF TRANSPORTATION

BEFORE THE

UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE
SUBCOMMITTEE ON SPACE AND AERONAUTICS

FEBRUARY 13, 1995

INTRODUCTION

Good morning Chairman Sensenbrenner and members of the Subcommittee on Space and Aeronautics. I appreciate the opportunity to testify here today and to tell you of some of the exciting things that are going on in commercial space transportation and some of the areas we feel need to be addressed. And, since this hearing is preparatory to authorization of the Fiscal Year 1996 budget, I will address what we see as the resource needs to enable us to carry out our responsibilities in ensuring the U.S. safe, economical, and assured commercial access to space.

I know, Mr. Chairman, that you have long expressed an interest in innovative approaches to supporting commercial space development, and we look forward to working with you along those lines.

Mr. Chairman, I know that you and some veteran members of this subcommittee are very familiar with the history of commercial space operations in this country, but in view of the significant number of new members joining the subcommittee this year, please permit me to recount a brief history of this industry.

BACKGROUND

From the beginning of the space age until relatively recently, space launching in this country was a strictly government activity, with NASA launching both scientific and commercial payloads and the military carrying out its own programs.

In the early 1980's, some visionaries dreamed of a commercial, private sector, space transportation industry and endeavored to make it a reality, leading to the recognition of the need for some coherent government oversight and regulatory focus, rather than the fragmented and debilitating need to deal with various government concerns and requirements piecemeal. Among the results were the Commercial Space Launch Act (CSLA) of 1984 and the establishment of the Office of Commercial Space Transportation (OCST) within the Department of Transportation.

Through this Act and subsequent policy decisions, OCST was given the responsibility of ensuring the safety of this activity through a process of licensing commercial space launches and launch site facilities, determining insurance requirements for launch operators, facilitating access to government launch facilities, advising other government agencies on the vehicle and infrastructure needs of the commercial launch sector, and in various ways promoting the growth and international competitiveness of the U.S. commercial space transportation industry.

Little happened at first in this country, due to the apparent availability of low cost shuttle launches and related shutdown of expendable launch vehicle production lines. However, the European Space Agency nations, having acted on their determination to not be dependent upon the shuttle, had developed their Ariane expendable launch vehicle and were already operating an alternative to the shuttle out of Kourou, French Guiana.

The Challenger disaster in 1986 led to the recognition that the launching of commercial payloads was not the best use of the shuttle and the decision by McDonnell Douglas, General Dynamics and other traditional U.S. launch vehicle manufacturers to go back into production and become commercial launch service providers. The CSLA gave them the ability to use federal, primarily military, launch sites on a direct cost reimbursement basis.

Starting back up took time, however, and the first commercial licensed launch did not take place until early 1989, more than three years after the Challenger tragedy. In the meantime, with no Western alternative, the ESA Ariane rocket built up an early lead in launch contracts which set the stage for its current position of leadership in commercial launching.

The challenge before us today is to restore the U.S. to its long-held position as the dominant supplier of launch services to the world.

CURRENT STATUS OF THE COMMERCIAL SPACE LAUNCH INDUSTRY

From that 1989 start, the U.S. commercial space launch industry has grown. In spite of a few failures in a young and complex undertaking, the industry appears on the verge of attaining a degree of maturity. We have had 45 licensed commercial launches to date, including 15 each on Atlas and Delta vehicles. Launch operations have taken place from Cape Canaveral Air Force Station in Florida, White Sands Missile Range in New Mexico, Vandenberg Air Force Base in California, Wallops Flight

Facility in Virginia, and Kauai Test Facility in Hawaii.

Launch vehicles, such as the Atlas and Delta, have been significantly improved in payload capacity and avionics. New vehicles have been introduced or are under development. Our commercial space launch manifest lists 17 launches scheduled for the remainder of this calendar year, although some of these could slip.

A LOOK AHEAD

In spite of this growth and progress in the last five years, we believe the next twenty years will witness more significant changes in space commerce than those which have occurred since the dawn of the space age. We are excited about the long-range outlook for the commercial space transportation segment. We have a vision of space as a place to do business, and to do it in an increasingly commercial manner. On the present course, commercial space launches annually will potentially outnumber government launches within the next few years, and we believe this trend will continue.

Satellite communications is already a $6.5 billion (1994) international industry, (of which $580 million and growing represents the U.S. space launch industry) using primarily geostationary (GEO) satellites 22,300 miles above the equator. Mobile systems to carry individual voice and data communications through constellations of numerous low-earth-orbiting (LEO) satellites are poised to add a whole new dimension to this industry. The FCC recently approved licenses for the Iridium, Globalstar, and Odyssey LEO systems to go with the previously approved Orbcomm system. A significant number of these satellites are expected to be launched on U.S. vehicles.

By the turn of the century, global mobile communications satellite systems and services, including geostationary and non-geostationary, are projected to represent a $20 billion market, of which $11 billion would be satellites, launches and ground equipment.

Companies are already well into plans to exploit the many benefits to be gained from earth imaging from space. These include environmental monitoring, agricultural assessment, mineral exploration, and even traffic management.

New and increasingly commercial uses of Global Positioning System (GPS) satellites are being developed, and satellites committed to data transmission and paging are ready for launching.

And, of course, there is the essential contribution that satellites will continue to make to the development of the National and Global Information Infrastructures (NII and GII) through the unique capability they add in connecting anyone with anyone else, anywhere on the globe.

We in the U.S. will only have control over our own access to these many benefits so long as we have reliable and cost effective launch capability.

We look forward to the day when work will actually be done in space on a commercial basis and when travel to, through and from space will be routine. This is, of course, looking well into the future, but decisions we make now will do much to determine whether the United States and its business community will lead the way.

Manufacturing and technology development, materials processing and crystal growth in space are ideas which need to be pursued for commercial applications. Some may not prove economically feasible, or may be further in the future than we now see, but if this nation and our private sector do not lead the way, others will.

NATIONAL SPACE TRANSPORTATION POLICY

On August 5, 1994, the Clinton Administration announced a new National Space Transportation Policy, and the White House, the Department of Transportation (DOT),and the Department of Commerce (DOC), are currently finishing up details on an implementation plan. This policy built on earlier work, (such as the Augustine Report and the Moorman Study), in which OCST participated, and also reflects input from our Commercial Space Transportation Advisory Committee (COMSTAC), which provides industry expertise and perspective to The Secretary of Transportation.

I believe this policy and implementation plan provide the context within which we, in partnership with Congress, can take those steps needed to ensure the health and international competitiveness of the U.S. space transportation industry.

The plan lays out the roles and responsibilities of government departments and agencies, and other witnesses will, I'm sure, address some of these. We, at Transportation, have the primary responsibility for addressing the international competitiveness of the U.S. launch industry, and, with the Department of Commerce, developing public/private partnerships that will cooperate with NASA and the Department of Defense in the development of the next generation reusable launch vehicles and the evolved expendable launch vehicle (EELV) family, respectively.

Until the EELV family becomes operational, upgrades to the traditional expendable launch vehicle fleet are essential in order to stay competitive while awaiting the next generation, an important interim step. These measures are needed in order for launch providers to remain competitive in the short run, and to reduce the government's own launch costs during that period.

OCST participated in the grant selection process for the 1993 and 1994 Air Force Dual-Use Infrastructure Grant Programs.

RE-USABLE LAUNCH VEHICLES

We believe that the re-usable launch vehicle, such as the single-stage-to-orbit (SSTO) concept, is a promising technology to bring about a reduction in the cost to reach space. Such vehicles have the potential to provide highly reliable, safe and economical access to space.

There are, in fact, some promising entrepreneurial efforts underway along these lines. We are following closely the efforts of small, risk-taking private firms, which are actually building hardware with private capital to demonstrate their vision of how this can be done.

DOT is conducting pre-license consultations with larger, well-established commercial companies that are developing reusable launch vehicle technology to acquaint them with safety regulations. We advise them on approaches to safety issues and other requirements for vehicle design, operation, and maintenance.

TECHNOLOGICAL INNOVATION

Companies such as American Rocket, with their pioneering work on hybrid propellant, Orbital Sciences Corporation, with their air-launched Pegasus and other innovations, and the Commercial Experiment Transporter (COMET) orbital re-entry vehicle on which several firms are cooperating, are only a few examples of the private sector pushing the technological envelope.

In another approach, we are working with a major U.S. aerospace firm pursuing an innovative commercial launch concept that involves collaboration among partners in this country, Russia, Ukraine, and Norway. This new "sea launch" venture would operate out of a U.S. home port and use a mobile floating launch platform to provide the optimum launch location for each specific kind of satellite.

REGULATORY ISSUES

These new technologies pose new and unique safety/regulatory issues. No longer is the government necessarily performing technical oversight over design and development of these new vehicles and technologies. DOT is the government agency responsible for assuring public health and safety as concerns the operation of these vehicles and we must develop new skills and regulatory tools to keep pace with the evolving changes occurring in this industry.

The development of industry standards is a desirable goal to increase efficiency in both industry operations and the regulatory process. To stimulate and focus industry interest in such standards, OCST sponsored a workshop under the auspices of the American Institute of Aeronautics and Astronautics to address the benefits to the international space transportation industry. I am pleased to report that this effort is on-going, with plans to have the first range safety standards available for industry review later this spring. We believe this will become a springboard to streamlining the regulation of the commercial space transportation industry by allowing the industry to define the standards by which it will provide for safe and reliable space systems.

During 1995, DOT is considering a number of activities to help achieve this vision of commercial space transportation in the next two decades. Allow me to mention a few:

o **Launch and Site Regulations:** DOT hopes to update regulations concerning commercial launches and the operation of commercial launch sites. Upon consideration of information gathered at a public meeting in October of 1994, we intend to enhance both the definition and clarity of the 1988 regulations while retaining the flexibility necessary to encompass new space transportation systems developed since then.

o International Trade in Space Launches: DOT has helped to negotiate international agreements which promote market stability and competition as China and Russia enter the world space launch market and transition to market economies. OCST leads the interagency Working Group on Information, which is responsible for monitoring Chinese and Russian compliance with the agreements. We are analyzing the need for international agreements with market economies (e.g., Europe and Japan) to provide for free and fair competition in space launches. OCST supports the USTR by conducting LEO and GEO market assessments enabling the USTR to allow foreign launch suppliers to participate without disrupting the market.

o Vehicle Technology: DOT is working closely with DOD, NASA, and DOC to develop a common set of spacelift requirements to serve civil, commercial, and national security needs. DOT is also working closely with the other agencies to develop a coordinated technology plan to serve the future needs of the three space sectors.

o Space Launch Infrastructure: DOT is working closely with the U.S. private sector, existing DOD and NASA launch sites, emerging commercial spaceports, and interested state governments to develop an inventory of the infrastructure needs of the commercial space transportation industry.

We, at DOT, view our role as ensuring the safety of commercial space transportation. As you may recall, I requested the DOT Inspector General to review the procedures, processes, and organizational structure of the Licensing and Safety Division of OCST. Copies of the IG's report and our implementation plans for the recommendations made were provided to members of the subcommittee last year. We are well on our way to implementing those recommendations. We are in the process of updating the regulations, providing for electronic communications with our constituents, automation of the license application process, expanding our in-house expertise (three added personnel in 1994 brought in excess of 70 years aerospace experience to the office), and enhancement of the two-way communications between the licensing staff and the license applicants.

Our goal is to work with industry. We welcome innovation and enterprise, commensurate with our responsibility to maintain safety. We also want to provide clarification to the site operator licensing process to facilitate development of this new industry and associated services.

INFRASTRUCTURE

Transportation infrastructure is, after safety, the principal operational concern of DOT, and space transportation infrastructure is probably undergoing, proportionately, the greatest transformation of any mode of transportation. While commercial launches to date have all taken place from federal facilities, work is proceeding on planning and development of four commercial launch sites in the U.S.

- Western Commercial Space Center located at Vandenberg Air Force Base in California has just received a $30 million investment from ITT and plans to support a variety of small launch vehicle operations.
- Spaceport Florida Authority is developing one or more commercial launch sites at Cape Canaveral and elsewhere.
- Alaska Spaceport plans development at Kodiak Island that would support commercial polar-orbital and suborbital launches.
- Southwest Regional Spaceport adjacent to White Sands Missile Range in New Mexico is planning to support commercial sounding rocket activity and new launch systems. It was the site for testing McDonnell Douglas's Delta Clipper, a single-stage-to-orbit concept vehicle. Operations at Southwest will include unique operations of land overflight.

DOT has the statutory responsibility to ensure protecting public safety in licensing operations at these facilities and is looking at innovative partnerships and other ways to be supportive of these groundbreaking undertakings.

We look to the implementation of other strategies, such as anchor tenancy, termination liability, innovative partnerships, and imaginative tax policies for commercial launch providers and spaceport developers to leverage private capital into space commerce.

FY '96 BUDGET REQUEST

Against this backdrop, Mr. Chairman, I note the President's FY 1996 request for the Office of Commercial Space Transportation is $6.541 million. It represents an increase of $497 thousand, or 8%, over the enacted FY 1995 budget. Three quarters of this amount is for personnel compensation, largely to annualize the increase of five positions enacted in FY 1995. The FY 1996 request does not seek any additional personnel.

The FY 1995 staffing increases were enacted in response to the demands placed on OCST by the growth in the commercial space launch industry and its increasing complexity and diversity. It is responding to industry's desire for more explicit guidance concerning licensing requirements.

Future resource needs are difficult to predict in a climate of diversifying technology and proprietary developments that can suddenly make yesterday's projection obsolete. A radical development in new vehicle technology, a dramatic breakthrough on cost per pound to orbit or other development could greatly alter the Office's requirements to be able to ensure safe and environmentally responsible commercial space transportation.

As part of the President's Reinventing Government Initiative, we, and all federal agencies, are reexamining our mission. We are seeking "customer" input, as we ask whether the mission could be accomplished without federal investment, what the benefits of competition are, and ways to cut red tape and empower employees.

This concludes my formal remarks. Once again, I thank you for inviting me to testify this afternoon. I would be happy to answer any of your questions.

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Mr. SENSENBRENNER. Thank you, Mr. Weaver.
Mr. Calhoun-Senghor.

STATEMENT OF KEITH CALHOUN-SENGHOR, DIRECTOR, OFFICE OF AIR AND SPACE COMMERCIALIZATION, DEPARTMENT OF COMMERCE, WASHINGTON, D.C.

Mr. CALHOUN-SENGHOR. Thank you, Mr. Chairman, Congressman Hall, members of the committee. It is a pleasure to be here today. I think this is a very important and timely hearing. I think this is a very important topic and I appreciate the opportunity to discuss it on behalf of Secretary Brown and the Commerce Department.

First of all, let me say that we are, quite frankly, entering a new era in space. We are entering a time where commercial space quite frankly was an oxymoron to an era where it is no longer and should no longer be an oxymoron. The fact of the matter is that very much of what we are seeing now in terms of commercial space and in terms of the potential for commercial space is already here, and in fact, a lot of what we cannot imagine will be here very, very quickly. I just wanted to touch on a couple themes and then allow the committee to ask any questions that it wanted.

We are at a point now where the space race is no longer, from a commercial point of view, to the moon. It is to market. Many of the principal products and services that we will be using and that our children and grandchildren will be using in the 21st Century are things that will be based on technologies that will be using space and the commercial aspects of space, be it in applications or in the actual products.

For example, as has already been touched on by both Administrator Goldin and Mr. Weaver, here, that the global information infrastructure that we are looking at is essentially virtually upon us. There is, in the form of the Leo constellations, going to be the opportunity for worldwide global mobile communications based on space assets and the average American citizen will not care, nor should they care, that this is being based on space-based assets. It is a time, I think, where space and the use of space should become and is becoming commonplace.

People aren't asking how their phone calls are getting to them. They are not asking how it is that the use of remote sensing imagery that they use in terms of their everyday lives, real estate or location data, whether that is based on a satellite or based on aerial photography, but the fact of the matter is that many of these applications are changing the ways that we do business. They are changing the ways in which we are interacting with each other. They are changing the way in which we interact with our government, and in so doing, it is making space relevant to the average citizen, something which is extremely important, particularly as we enter a market where the space-based markets will be creating the jobs for our children and for our grandchildren.

I think that the growing web of information that we are looking at, be it in the satellite imagery, commercial remote sensing, which this committee had very much to do in terms of bringing the realization of that idea to fruition, or location data, which is the commercial use of global positioning satellites, or voice in these small Leo constellations or data through networks.

All of these are applications that I think have very exciting possibilities and we haven't begun to realize, and which are extremely important in the way that we will be working with each other.

I think that the commercialization of space is in many ways a return on the investment, return of investment on this country's Cold War investment because much of this is a defense conversion issue.

For example, remote sensing, and even our launch policy in many ways, is the realization of an investment that we made in Cold War terms, but which now can actually pay dividends today and that, I think, is extremely important. And I think the President's remote sensing policy had the support of the DOD and intelligence community largely because it struck the balance between our economic security and our national security and asked for a return on that investment.

I think that working together with this committee and with private industry, I think we want to pursue the kinds of private public partnerships that I think have made many of the efforts that we have undertaken thus far so successful, be it the national space transportation policy, which actually for the first time explicitly recognizes the role of the private sector in the development of commercial launch vehicles, not just in the development or in the production, but also in the operation.

It leaves open all options and I think that a lot of that is what we are seeing in terms of how we pursue our next generation launch vehicles. I think that is very, very important as we look towards the future and say, what do we see out there on the horizon? I thank you, Mr. Chairman.

[The prepared statement of Mr. Calhoun-Senghor follows:]

Testimony of

Keith Calhoun-Senghor

Director, Office of Air & Space Commercialization
United States Department of Commerce

before the

Subcommittee on Space and Aeronautics
Committee on Science

United States House of Representatives

Monday, February 13, 1995

Testimony of Keith Calhoun-Senghor
Director, Office of Air & Space Commercialization
U.S. Department of Commerce

before the

Subcommittee on Space and Aeronautics, Committee on Science
United States House of Representatives
Monday, February 13, 1995

Mr. Chairman, Mr. Hall, members of the Committee, on behalf of Secretary Brown and the Department of Commerce I thank you for inviting me to testify before you today on the accomplishments and upcoming policy priorities of the Office of Air and Space Commercialization.

As you know, the Office of Air & Space Commercialization has been a part of the Office of the Secretary since its creation. As Director, it is my responsibility to advise the Secretary and Deputy Secretary on the formulation and implementation of policies related to commercial space. The purpose of these policies is to foster the growth and international competitiveness of the U.S. commercial space sector, and promote the commercial use of space by U.S. private industry.

With the recent explosion of growth in commercial space, we deal with issues that include: traditional uses of space such as remote sensing and telecommunications; emerging markets and launch applications such as the commercial use of GPS and the potential for commercial production in space; and space launch and transportation concerns such as international launch trade agreements and the policies regarding next generation space launch vehicle development.

I will review for you some of our major policy initiatives, giving you a sense of what we have done in the past two years, and what we plan for the future. First, however, let me give you some background information about our office.

Background:

The OASC was created as part of the Office of the Secretary to work with the private sector, other Federal agencies, state and other governmental entities to develop national policies with respect to the commercial use of space. It was also designed to work with the various bureaus within the Commerce Department, including the Bureau of Export Administration (BXA), International Trade Administration (ITA), National Oceanic and Atmospheric Administration (NOAA), National Telecommunications and Information Administration (NTIA), Technology Administration (TA), and Office of General Counsel (OGC), to coordinate Commerce Department policy on commercial space related activities in DoC.

Mr. Chairman, we at the Department of Commerce, and throughout the Federal Government, are re-examining our mission through the National Performance Review. We are seeking customer input and asking whether our mission could be accomplished without Federal involvement, what the benefits of competition are, and how we can cut red tape and empower employees.

In FY 1994, OASC operated with a staffing level of 4 personnel and a funding level of $443,000. In FY 1995 and FY 1996, we will continue to operate with 4 personnel and funding levels of $450,00 and $457,000 respectively.

The Department's FY 1994 accomplishments include active involvement in developing the President's policy on commercial satellite remote sensing, as well as the President's National Space Transportation Policy. We have also been involved in a number of smaller initiatives such as the Dual Use Launch Infrastructure Grant Program, the Aeronautics and Space Report of the President, as well as the Orbital Debris and Space Nuclear Power interagency working groups. Our priorities for FY 1995 include follow-up on remote sensing, working with other agencies to implement the space transportation policy, completion of a new space launch trade agreement with China, and the publication of Space Business Indicators, a comprehensive source of commercial space market trends and information. We expect remote sensing, the launch policy, and international trade negotiations to continue as focuses into FY 1996, we plan to update Space Business Indicators in that year, and we see orbital debris, global positioning, and space-based manufacturing as emerging issue areas.

Remote Sensing:

In March, 1994, due in large part to impetus provided by this sub-committee and full committee hearings on the subject, Deputy Secretary of Commerce David J. Barram, on behalf of the Administration, announced a major policy change in the treatment of commercial remote sensing imagery and systems. The U.S. Policy on Foreign Access to Remote Sensing Space Capabilities allows for expanded sales of commercial images from space and the potential for the export of remote sensing systems themselves under State Department jurisdiction.

This policy represents a major milestone in the commercialization of space-based imagery and unleashes the potential of a critical 21st century information technology at a time when the international market for space-based imagery appears poised for significant expansion. It should open the way for U.S. aerospace firms to aggressively compete in a $400 million market worldwide, a market which could grow to more than $2 billion by the year 2000. The geographic information systems market (which is the market for images incorporating demographic or technical data with digital maps) could be in the range of $5 to $15 billion by the turn of the century.

The remote sensing policy also aids the defense industry in its efforts to find new commercial applications for defense technologies. Moreover, the data produced by this technology will include environmental and geographic information that will greatly advance emergency management and rescue, disaster relief, mineral exploration, crop management, cartography, marketing, real estate and a variety of other commercial endeavors and become an important product to be delivered over this country's National Information Infrastructure (NII) and Global Information Infrastructure (GII).

In less than a year since the policy was released, the DoC bureau within NOAA tasked by the Land Remote Sensing Policy Act with remote sensing licensing, the National Environmental Satellite Data Information Service (NESDIS), has granted five operator licenses to U.S. firms for the operation of commercial satellite remote sensing systems. A total of six U.S. licenses have been issued since January of 1993. The United States is not alone in the satellite data provision field, however. The European Space Agency, France, Russia, Japan, and India already have satellite remote sensing capabilities, and Korea, China, Canada, and Israel have plans to enter the commercial satellite remote sensing field.

This office will continue to foster the U.S. technological lead in this area, encouraging U.S. preeminence in the worldwide commercialization of high resolution imagery. The Department will work closely with the Departments of State and Defense, the Intelligence Community, and industry in the implementation and refinement of this policy, balancing economic, national security, and foreign policy concerns.

Space Launch Trade Agreements:

This office, in coordination with ITA, also represented the Department, working with the United States Trade Representative, Department of Transportation, State Department, and others in the U.S. government to help increase the size of the world market for space launch without jeopardizing economic advantages that the United States has gained in satellite production.

Launch-service trade agreements negotiated with the governments of Russia and China strive for an environment under which introduction of launch vehicles from economies in transition will cause minimal economic disruption to the international launch market. These agreements will allow U.S. launch service providers to compete fairly with foreign providers for international business, will allow satellite constellation operators assured access to launch capability, and aid the transition of formerly non-market economies to economies based on fair trade.

Just last month the Department participated in the initialing of a new agreement with China. The formal signing will take place in February or March of this year. Both that agreement, and the Russian launch agreement signed in 1993, call for annual consultations through the year 2000. We will be taking part in that process and will be working with the Office of the U.S. Trade Representative on a possible agreement with the government of the Ukraine.

Moreover, in the coming years OASC will be involved in the monitoring and implementation of the agreements already signed, as well as in negotiations of possible new agreements with other non-market foreign launch providers. We view these agreements as an integral part of the Administration's plan to develop low-cost, dual use, reliable access to space and foster fair competition in the international launch market.

National Space Transportation Policy.

The recent Presidential policy on space transportation (U.S. National Space Transportation Policy, NSTC-4) explicitly recognizes the importance of private sector input into government space launch policies and activities. As a result, the President's policy mandates that the Department of Commerce and the Department of Transportation do two things:

1. explore new and innovative relationships between the government and the private sector, and

2. assure private sector involvement in the development of vehicles.

In response to the policy, OASC worked with Deputy Secretary Barram to organize a Government-Industry Roundtable of 25 CEO's from the launch, satellite manufacturing and satellite operating community to listen to private-sector concerns and suggestions on ways in which industry and government could work together and get industry more involved in the design, development, and operation of our next generation launch vehicles.

As a result of this meeting, OASC and the Department of Transportation's Office of Commercial Space Transportation are refining our policy implementation plan that spells out specific means of promoting the international competitiveness of our space transportation sector. With industry, NASA, the Department of Defense, and the Congress, our two offices will examine the role of the private sector in the design, financing and development of U.S. next generation launch systems, exploring innovative industry-government arrangements like risk sharing, tax incentives, equity participation, and anti-trust exemption.

We are also working to see that the commercial voice is heard in the initial stages of the government acquisition of launch vehicles. Through the National Spacelift Requirements Process, an interagency working group from the Departments of Defense, Commerce, and Transportation, NASA, and the intelligence community, we plan to develop a common set of spacelift system requirements that capture the needs of the defense, intelligence, civil, and commercial space sectors. These common requirements, ranging in concept from "mass to orbit" to "customer satisfaction", will influence the future development of medium to heavy launch vehicles.

We feel that the future of the U.S. launch industry, and the ability of the U.S. government to get to space economically and reliably, depends on the kind of industry-government partnership we have begun under this policy.

Emerging Space Applications:

Technological innovation and scientific know-how is leading to new and exciting space-based activities at a breathtaking pace. We have seen this in the commercial application of Global Positioning System information, the development of world-wide wireless communications constellations, and the advent of dual use launch facilities known as Space Ports.

OASC will keep an eye on future trends in commercial space not only by supporting the development of unique and innovative space applications where we can, but by providing market information for making important space business choices. Our plans include investigating ways to remove impediments to a privately-financed, next generation commercial space-based production facility; consulting with private Global Positioning System equipment manufacturers to examine the application of GPS technology to the National and Global Information Infrastructure and the every day utility of accurate, world-wide position information; and examining the role of satellites and wireless communication in the GII. We will also produce an updated edition of *Space Business Indicators*, a 1992 publication that highlights trends in the commercial space arena.

In closing, Mr. Chairman, Secretary Brown has made a commitment to promote the growth of U.S. high tech industry. We at the Office of Air & Space Commercialization are continuing that commitment by encouraging the cutting-edge advances made in commercial space while at the same time supporting U.S. national interests for ourselves, and for our children.

Mr. SENSENBRENNER. Thank you very much. Pursuant to the chair's announced policy, members of the subcommittee, including the Chair, will be recognized for five minutes each for asking questions. Those who were here at the beginning of the hearing will be recognized alternately by party in the order of seniority and those who arrived after the hearing began will be recognized without regard to party or seniority in the order of appearance, so that there will be a five-minute rule for asking questions and I would ask the witnesses to try to be as sharp as possible and not to filibuster their answers to the questions so that each member of the subcommittee can ask as many questions as possible in five minutes.

So the Chair will recognize himself for five minutes and, Shana, would you please start the timer?

Mr. Goldin, as you know, you and the subcommittee got the bad news that the OMB had cut $5 billion out of the out year NASA budget. We on the subcommittee would like to get an authorization bill out of subcommittee and out of full committee before the Easter recess so that we can get some Floor time and influence the Appropriations Committee.

Because you stated that you won't be able to figure out how to absorb the $5 billion, don't you think it would be prudent for this committee and the Appropriations Committee to defer authorizing and appropriating funds for the new starts until after we figure out how much money we have for the existing programs?

Mr. GOLDIN. We have a difficult situation here. I don't know how to make a promise I can't keep and we are going to be working until May 17th. If you would give me a few moments to answer that question later in the hearing, I don't want to shoot from the hip. I think it is a very important question you asked and I would like to give it some thought.

Mr. SENSENBRENNER. The observation that I would make is that I think by May 17th, the train will have left the station, because the Appropriations Committee has two of the three weeks of their Easter recess canceled so that as many of the appropriation bills as are possible will be ready to go once the House goes back into session on May 1st and it may very well be that the HUD, VA and Independent Agencies appropriation bill will be one of them.

We on the subcommittee want to have input and it is the Chair's intent to introduce a multiyear NASA authorization bill sometime within the next four weeks and then to have a public hearing next month with nonadministration witnesses so that we can get our job done before April 7th. So I would ask you to be cognizant of that.

I am not partial to funding any new starts until we see what is done with this $5 billion, because I would rather not authorize a new start and then end up having to deauthorize it or defund it because we need the money elsewhere.

Secondly, let me express for the record my concern about shuttle safety. This was discussed last year at the authorization hearing on February 23rd, 1994, and in response to questions by Mr. Bacchus of Florida and Mr. Walker relative to shuttle safety, you said, and I quote, "Maybe we will know something more next year, but right now I have an obligation to tell you and the way we are working at it in NASA is there is one human being in charge of the Shuttle Program. It is General Pearson, and I gave him instructions which said, General Pearson, I will press you as hard as possible to cut the cost of the shuttle, but when you come to the point where it is unsafe to operate, you say so. And he said, "I am prepared to live with the budget you have," unquote. And we could have him come up and say that, but here is what he told me. Quote, "I am prepared to live with the budget you have," unquote. Knowing what I know now, I am not—I don't know where I could cut it anymore. That was his position. I have to respect that.

Well, General Pearson has resigned from NASA. And there are concerns, although he, being a good soldier, hasn't expressed them publicly, that there isn't enough money to ensure safe operation of the shuttle. Where, in this budget that you are defending today, is the assurance that there is the money there to operate the shuttle safely?

Mr. GOLDIN. Let me say that all studies we have undertaken at this point are nothing more than studies. We do not have results. We have not planned any further cuts, and for the record, I will submit a letter which I sent to Dr. Wayne Littles, who is the Associate Administrator for the Office of Space Flight, instructing him not to make any cuts that impact shuttle safety as part of this whole process.

And as far as I am concerned, when we go through this whole process and we have the results, if more money is required for the shuttle, we will put in more money. We are in the middle of a study. We have not yet made any declarations about where cuts will be.

Mr. SENSENBRENNER. Of course, we can study things forever and if there is a tragedy, that is something that is irreplaceable, and the one person upon whom you placed your faith on the record and in the transcript has decided to abruptly leave NASA, and that is a matter of grave concern by this subcommittee on a bipartisan basis.

We do not want another Challenger disaster and the melding of the station and shuttle budgets in 1994 meant that any cost overrun in the station would end up being absorbed in the shuttle.

Well, my time is up and I now recognize the gentleman from Texas, Mr. Hall.

Mr. HALL. I thank you, Mr. Chairman. Mr. Goldin, you stated that you don't want to cut programs and instead that you intend to fundamentally restructure NASA. You have not yet specified exactly how you would propose to restructure the space agency or what level of cost savings would be achieved and when those cost savings would show up on the horizon.

You have mentioned possible consolidation and elimination of facilities, possible elimination of one or more field centers or conversion to government-owned, contractor-operated centers, consolidation of shuttle contracts, civil service RIF and on and on. When will you know? You mentioned May 17th, but when will you know the cost and benefits of the various restructuring options? Are you going to know those as you go or do you know them now or do you have a ballpark figure for them?

Mr. GOLDIN. We are going to work through it. As we collect data, we will be pleased to share it with the committee. We are still right at the start. I mean, we are just trying to react to the January 12th announcement, but I want to make one thing clear, when we get done, if we can't cut infrastructure, we will cut programs and we will recommend appropriate programs to be cut. We just don't have the answers.

I also want to emphasize one more time that we are not cutting the shuttle budget. The shuttle budget is as it was when General Pearson was there. We are looking at how we could do a better job with the shuttle. So until we have the results of the studies, we are not going to do anything precipitous, and, in fact, in my opening statement, I felt we would need '95 and '96 in order to assure that we had a stabilization of the program before we would take the appropriate cuts.

Mr. HALL. Well, would it be asking too much if you, as you make these decisions leading into the 17th of May, that you stay in touch with the Chairman of this subcommittee, Mr. Sensenbrenner, or— and Mr. Walker and Mr. Brown to where they can stay in touch with us?

Mr. SENSENBRENNER. And without objection, the gentleman from Texas will be included, too.

Mr. HALL. Well—

Mr. GOLDIN. We will not make a decision without consulting with the committee first.

Mr. HALL. And I think the President's budget cut is $5 billion out over five years. He also included a new launch vehicle. I think you have said that we need between $730 million to $1.1 billion over the next five years for that. Is that right?

Mr. GOLDIN. Yes.

Mr. HALL. At the end of five years, what happens?

Mr. GOLDIN. We will be in a position to make a decision. This is not a decision that will be made without consequence, because if we decide not to proceed with a new launch vehicle at the end of five years, we are going to have to make a five to $10 billion investment in the shuttle.

So we felt it was crucial that the President of the United States have the appropriate data when that decision has to be made to decide to go ahead with an upgrade to the shuttle or to go to a new launch system. If we make no investment over the next five years, this Nation is guaranteed that we are going to stick with the shuttle for another 20 years.

Mr. HALL. So you have some alternates? There are some alternatives, are there not?

Mr. GOLDIN. Yes. But you have to invest the money up front to have the decision, but this money is not being invested to start a new launch vehicle program. This money is being invested to collect data, and instead of having paper studies, we are insisting that industry fly—have equipment flying so that we can really understand the operational course.

Mr. HALL. At the end of five years, is it your belief or maybe even hope that industry might take over launch vehicles and we could buy trips on launch vehicles?

Mr. GOLDIN. If we could get NASA out of the business of developing a new launch system and let industry develop it because of a very significant commercial market and NASA just buy services from industry, that would be my highest desire.

Mr. HALL. And what happens if industry fills their needs and NASA has to, then, go to a vehicle for their own specific requirements? What would you do?

Mr. GOLDIN. We would have to make a decision, are we going to spend $10 billion on the shuttle, go back to the SSTO or else do we go to the SSTO, but we will never know unless we make an investment now to make a decision in five years.

Mr. HALL. Because I don't like to hear that dangle on, I am going to yield back my time now and maybe come back to you in a minute because I do have some questions of the other two gentlemen.

Mr. SENSENBRENNER. The gentleman from California, Mr. Calvert.

Mr. CALVERT. Thank you, Mr. Chairman. Mr. Goldin, the President's budget appears to give back some of the decision-making process back to the Members of Congress. There is the $5 billion that has been mentioned, the unresolved percentage reductions next to a handful of new program starts, such as the New Millennium spacecraft, Stratosphere Observatory for Infrared Astronomy, the Solor Infrared Telescope Facility.

I would like to call your attention specifically to the Gravity Probe B Program that contains the first line of $51.5 million funding for the program, and then in the next line there is a $51.5 million offsetting reduction. This is later explained by a paragraph that says, Gravity Probe B is under a National Academy of Sciences review and if the review is favorable, than the $51.5 million program cuts will need to be made.

My first question is, why should there be another National of Academy of Sciences study? The Gravity Probe B Program has been studied by NASA since 1984. It has undergone 17 studies and reviews to validate the scientific merit of the program, and suddenly you want to study it again. Can you comment on this?

And my second question, which may be associated to that, is there any other programs of note that face a similar situation where there is continuous studying being made even though the previous studies and reviews validated the scientific merit of that other program?

Mr. GOLDIN. I wish I could say that we are going to have stability and leave every one of our programs alone, but the fact of the matter is I don't get a choice in setting the level of the NASA budget and I have compassion for the people working on this program, but we have looked at AXAF and cut it by more than a factor of two. We have made major cuts in Cassini. The View spacecraft was $300 million to develop. We cut it to $100 million and Gravity Probe B remains the third largest science program we have at NASA.

Noble laureates walked into my office and key members of the scientific community walked into my office and they told me that they had serious doubts today about the viability, the scientific viability of Gravity Probe B. They said there were three issues associated with it.

One, they were unsure whether the accuracy of 10 to minus two on LANS tiering was adequate to have major scientific findings. Second, they said that in light of discoveries made since the Gravity Probe B mission started, they were concerned that we were doing redundant science.

And finally, they said they were concerned that even if it had accuracy of 10 to minus two for LANS tiering that we would be able to, in an engineering sense, guarantee that accuracy on orbit.

I cannot be judge and jury. We have tremendous budget pressures and I felt obliged to go to the leadership of the National Academy of Sciences and ask the best scientists and engineers in the country not to make a budget decision, but to resolve these open issues.

I can't have noble laureates walk into my office and tell me that. It is inappropriate for the Administrator to do that, and by the way, this is going to happen again and again until our budget gets stabilized. We are going to have to cancel programs, in spite of the emotion and the passion that goes into them, and we are in an orderly process and will do what is right, and the Academy said they will have us an answer by June 1st. We did not want to assign a program to put against it because then the academy would compare one against the other and we wanted a pure scientific input.

Mr. CALVERT. With regard to my second question, are there other programs of note where you have been studying these types of programs for such a long time and reviews have been made validating the merit and are we continuing to study them without canceling the program or continuing the program?

Mr. GOLDIN. SIRTF has been studied for 20 years now, and, in fact, we cut the cost of SIRTF from $2 billion down to about $500 million, if I remember correctly, and then went back to the National Academy and said, is this acceptable science? And they came back and said, yes.

On SOFIA we did the same thing. So there are other programs and on fuse, we cut it by—we said either get it to $100 million worth of development or we cancel it. So we are looking at other programs. We are not picking on Gravity Probe B. I have the highest regard for Stanford and the Lockheed Company. I wish we were in a different place, but we are not. The Congress doesn't give us extra money and, by God, the administration doesn't give us extra money and we have to take deliberative action.

Mr. CALVERT. I have a little more time. What is your long-term goal with NASA's budget in relation to space versus aeronautics?

Mr. GOLDIN. We will try and maintain a balance. We have got to have a partnership with the U.S. aerospace industry and there are things that we do in aeronautics that sometimes don't see its way into the marketplace, and we are entering into a very vigorous discussion with the aerospace industry to assure that we are getting maximum output from the precompetitive technologies we are working on. So we will try and maintain the balance we have right now.

Mr. SENSENBRENNER. The time of the gentleman has expired. The distinguished former Chairman of the Science Committee, the gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Sensenbrenner. In view of the large amount of interest and the large number of new Members, I am going to pass on my questions.

Mr. SENSENBRENNER. The gentleman from Florida, Mr. Weldon.

Mr. WELDON. Thank you, Mr. Chairman. I would direct my questions to Mr. Goldin. It is very early and we are just starting to analyze this budget in my office as well, but one of the things that caught our attention, we were looking at the '95 versus '96 authorizations for the various centers and we see a very modest increase for some of the other centers like Marshall. Kennedy Space Center is seeing a reduction. We weren't able to see how that is accounted for. I was wondering if you would be able to give me an insight into that.

Mr. GOLDIN. Sure. What monies the centers get are a dependent variable. We do not give monies to centers; we fund programs, and as we go through each of the programs, we try and establish what is the right dollar level for each program and the actual money that comes to a specific center is a fallout of that process.

Mr. WELDON. I assumed that was what was going on. I was just wondering if you might have more details on that. That may be a question I may need to submit to you in writing to get a breakdown on that.

Mr. GOLDIN. I would be pleased to get the details and the NASA Controller is here and I think it will take more than the two or three minutes we are allocated to answer, so we will be very happy to answer a detailed question in writing.

Mr. WELDON. Maybe these other questions we have you would be able to answer for me.

As I understand it, in November '97 we are to launch the first payload to the station, correct? And that is the functional cargo block component currently being manufactured in the Soviet Union or in Russia, right? I was curious, who signed the protocol to acquire that? Was that NASA or was it one of the subcontractors, Boeing or Lockheed?

Mr. GOLDIN. I believe it was Lockheed, but let me check. Yes, it was Lockheed.

Mr. WELDON. So who is ultimately responsible for delivery of the functional cargo bay to orbit in November then? Is it Lockheed?

Mr. GOLDIN. We are holding Lockheed accountable for that.

Mr. WELDON. The other question I had was, when will the ownership of that transfer from the Russians to Lockheed, when is that slated to occur?

Mr. GOLDIN. It is handed over 15 days after it is on orbit.

Mr. WELDON. Okay. The other question I had was just kind of a general question which perhaps you would be able to answer for me. I built a house a few years ago and a lot of my friends told me you need to allow for some cost overruns and sure enough, we had some cost overruns and I was very happy I allowed for that in my budgeting.

Do you feel that there is sufficient latitude in this station budget that we can accomplish the project? In other words, do you have breathing room in that for unanticipated developments?

Mr. GOLDIN. We have a $3 billion reserve against $15.1 billion to go. We have been building that reserve with time. In fact, we negotiated a much tighter contract with the Boeing Company in the process and we have eliminated all unresolved issues against the space station. So we do have a reserve. Is it adequate? I believe so. And I think time will tell, but in the last year, we have been—we made it through and we built the reserve as we went.

Mr. WELDON. Thank you. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentlewoman from California, Mrs. Seastrand.

Mrs. SEASTRAND. Thank you for being here today. Commercial space is the area that I have been very active in, both in California and now in Washington. As we know, this is an industry that presents tremendous economic opportunity, not only for my district on the central coast of California, but for my State, California, and most importantly for our Nation.

As you know, California has been a leader in commercial space and spaceport development. We are building the first commercial spaceport at Vandenberg and we are making good use of the government's $5 billion manned space investment. However, California has progressed largely without NASA.

Over the past eight years, NASA has funded 17 commercial space development centers to the tune of $1 million each and has contributed over $200 million on base and project funding. The major concentration of this funding has been east of the Mississippi. In fact, there is only two centers that are west of the Mississippi.

Recognizing that the money NASA does send to California is exclusively for manned space and some of that is actually siphoned off to Texas and Alabama, can you tell me why NASA seems so adverse to commercial space funding in California, and does NASA have any plans to increase its commitment to commercial space development in California?

Mr. GOLDIN. First, let me say that we do not award contracts based upon geographical location. The contracts get awarded based upon the merits of the proposals that we receive. California receives the largest share by a factor of two of all NASA funding and let me say, it is not all for human space flight. A large fraction of that money goes into programs like Cassini and AXAF, Gravity Probe B.

A third of our aeronautics budget goes to California, and that happened purely on the merit of the case. And in the case of the commercial centers for the development of space, we just had a peer review last year and eliminated a number of them and we are going to have another peer review this year.

The other thing we wanted to do with the commercial centers for the development of space is, not having an ongoing cottage industry in centers for the commercial development of space, but they are supposed to bring in commercial interests and eventually get it off the government payroll.

So we are going to work very aggressively to get these centers to step up and not live on government funding, but to enable the building of the spacecraft funding.

Now, if there is a specific proposal that the State of California has or that your area has, NASA will be pleased to consider it, but we will not make—and again, I don't want to come across as being harsh, but we cannot make any awards based upon needs of geographic areas. It has to be based purely on business merits and will this enable the space industry, space science, aeronautics and what have you.

Mrs. SEASTRAND. Another question that I would like to ask is the Mission to Planet Earth Program. The goal of the program, I understand, is for global change in earth systems and these satellites are polar orbiting missions which are launched from Vandenberg Air Force Base. Since that is the case, I wonder why headquarters are located in Maryland rather than near the California launch site, and what exactly were the financial or the managerial and technological reasons that made this decision?

Mr. GOLDIN. I think—I wasn't here when the decision was made, but let me assure you we are going through it very carefully now. As I said, everything is on the table as part of the zero-based review.

You generally do not locate your center of excellence for specific scientific enterprise where you launch it. You generally locate it where the scientific and technical expertise is. In the case of NASA, that has traditionally been at the Goddard Space Flight Center where we have, I believe, the largest number of earth scientists in the whole organization.

I think that is why they did it. I could go back and check, but we are very sensitive at this point to looking at the roles and missions of each of our NASA centers, and if we can't justify that it is enabling a commercial industry, enabling science or it is not overlapping with NASA centers or other government entities such as the BMDO, what have you, we are going to completely relook at it.

Everything is on the table, so we will be pleased to take any input you have and suggestions as part of this process and I make that offer to all the Members. We do not want to make a mistake. We want to do it right. We view this as the survival of the agency when we come out of the zero-based review.

Mrs. SEASTRAND. Another area that I would like to ask a question is why NASA maintains a full-time contingent at Vandenberg Air Force base to conduct operations. You only launch one or two vehicles a year from Vandenberg and what is the point of having ten or so civilian employees and 45 or so contractors maintaining a permanent presence there?

Mr. GOLDIN. Thank you very much. We will see if we can eliminate it. It will be our pleasure. If we have anybody that is doing work that is inappropriate, it is canceled.

Mr. SENSENBRENNER. The time of the gentlewoman has expired.

[The prepared statement of Mrs. Seastrand follows:]

Opening Statement of Representative Andrea Seastrand (R-CA-22)
NASA Posture Hearing 2/13/95

Mr. Chairman, as you know, the state of California has been a leader in the development of commercial space and spaceports. During my tenure in the California State Assembly, I was an active participant in drafting and supporting legislation which was designed to encourage spaceport development and to create an environment that was conducive to the overall growth and maturation of the commercial space industry. These are issues I intend to take an active role in promoting in Washington.

Our effort in California has enjoyed a good deal of success in the last few years. We have incorporated the manned space facilities at Vandenberg Air Force Base -- facilities that the federal government spent roughly $5 billion on in the past 30 years -- and we are currently building the nation's first commercial spaceport. The California Spaceport expects to open its doors for business sometime in 1996. There are currently 19 scheduled launches between now and the end of the decade and it is our expectation that many more will be added.

I must say that most of the success we have enjoyed in California has occurred not because of NASA, but rather in spite of NASA. In 1986, NASA instituted the Center for the Commercial Development of Space (CCDS) program which was supposed to be a pathway for U.S. industry to develop commercial markets by using the unique attributes of space. Since 1986, 17 CCDS's were established with base funding of $1 million each. Over this period, NASA has contributed a total of over $200 million in base and project funding.

Unfortunately, as it turned out, the commercial space pathway seemed to be exclusive to areas east of the Rockies.

The state of California has been hammered by a series of natural disasters over the last four years -- and some unnatural ones as well. Since 1988, it has been estimated that California has lost 16 percent of its U.S. defense spending with a resulting loss of 126,000 jobs. The state department of Finance has projected an additional 22 percent reduction in defense spending with a loss of another 81,000 jobs. In addition, California expects to lose more federal payroll jobs from its 27 military base closures than the rest of the states combined. The reduced military payroll results in job losses of around 101,000 and expected private sector defense industry job losses total around 300,000.

Despite these severe cuts, California remains a leader in the nation's defense effort and remains positioned to be a leader in the conversion to a peacetime economy. To do this, however, California must not be excluded from consideration for federal funds.

A consistent NASA argument has been that they already send $4.5 billion to California. Well that's true -- with a couple of caveats. First, some of that money is syphoned out for Johnson Space Center in Texas and Marshal Space Flight Center in Alabama. Second, most of the money is targeted for manufacturing, not high-tech engineering and research.

Third, what NASA fails to point out is that none of the money goes to commercial space technology development. The money goes to manned-space activities, specifically, Shuttle and Space Station. These are not commercial space projects.

Another area in question is the Mission to Planet Earth Program. The goal of the program is to understand global change and earth systems. These satellites are polar orbiting missions which launch from Vandenberg Air Force Base in California. Since that is the case I have to wonder why the headquarters are located in Maryland rather than near the California launch site. What exactly were the financial, managerial, and technological reasons were for this decision?

As Administrator Goldin knows, there is abundance of scientific expertise with regard to global change phenomenon in California. In fact the list is endless -- the University of California and California State University systems, Stanford University, National Laboratories at Livermore and Berkeley, NASA field centers at the Jet Propulsion Laboratory and Ames Research Center.

Another area in question is why NASA maintains a full-time contingent at Vandenberg Air Force Base to conduct operations. Since NASA only launches one or two vehicles a year from Vandenberg, what is the point of having 10 or so civilian employees and 45 or so contractors maintaining a permanent presence?

Some of these decisions appear to be part of larger government pattern. They match an equally illogical decision to house an earthquake research center in Syracuse, New York rather than in California where earthquakes occur quite regularly.

In this era of consolidation, downsizing, and limited federal dollars, more attention must be paid to where the money is spent and why. The United States has reached a point where getting the biggest bang for our buck is no longer a desire, but a necessity. It is the intention of this Member, as it is most of the Members on this Committee, to ensure that the Clinton Administration operates from this premise.

Andrea Seastrand

Mr. SENSENBRENNER. The gentleman from Indiana, Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman. Mr. Goldin, you testified this year that NASA is at a crossroads, and I would say that that firmly would put the space station in the cross hairs of budget cuts, given everything that has happened in the past year and over the past 10 years. Much has changed in the last year.

We have asked in the House for a constitutional amendment to balance the budget. We have different people talking about tax cuts ranging from $60 billion to $200 billion, and we have the obligation to look everywhere within our budgets to make tough decisions, to eliminate programs that either are not needed or haven't performed as well as they should have.

The space station, which is right up there on that wall, that is—do you recognize what version that one is?

Mr. GOLDIN. Yes, I do.

Mr. ROEMER. And that is the 1986 model; is that right?

Mr. GOLDIN. Yes, it is.

Mr. ROEMER. And that has been redesigned five times since then?

Mr. GOLDIN. That was on paper. Now we are building hardware.

Mr. ROEMER. And it was supposed to be completed in what year?

Mr. GOLDIN. I don't know. I wasn't here.

Mr. ROEMER. In 1994? 1995?

Mr. GOLDIN. Could be.

Mr. ROEMER. And the cost of the space station has gone from President Reagan's estimate of $8 billion to—what is your rough estimate right now given that we have already spent $12 billion on it?

Mr. GOLDIN. We have $15.3 billion to go for the development phase of this program, and on my watch, the cost of the program came down. I cannot sit here and defend something for which I had no responsibility, but I want to tell you, we are doing what we said we were going to do with the station.

Mr. ROEMER. So we have spent $12 billion. We will spend another $15 billion to construct it. That does not include the $1.3 billion per year from the year 2002—

Mr. GOLDIN. That is correct.

Mr. ROEMER. —to the year 2012 or 2013?

Mr. GOLDIN. Two thousand twelve.

Mr. ROEMER. And how many scientific missions will—if President Reagan designed this to do eight things, are we now going to get two scientific missions out of this from the original eight? What would you estimate?

Mr. GOLDIN. I will have to answer in writing what President Reagan asked for. I cannot speak to that which I have not been responsible for, but I am accountable and I will answer that question in detail.

Mr. ROEMER. Let me ask you another question about the functional cargo block, better known as the FGB. The inflation rate in Russia has taken down the value of the ruble by about 14 percent over the last five months. How is that going to impact on both the schedule and the cost and our commitment to this joint venture?

Mr. GOLDIN. We have negotiated a contract with Krunichev. It is a commercial contract between the Lockheed Corporation and

Krunichev. They are getting paid in U.S. dollars for that activity and they are going to deliver.

I want to tell you, we have gotten outstanding performance in our relationship with Russia in spite of all the concerns we have had and they are turning out to be one of our most reliable partners in terms of doing what they say they are going to do.

Mr. ROEMER. So what would your answer be? You have assurances, then, and you feel very confident that the November 1997 date is etched in stone and will not change?

Mr. GOLDIN. I can't say that. I want to tell you, there is risk in this program. We think it is reasonable risk, but I would not sit here and tell you I absolutely guarantee etched in stone that this will happen. This is a very tough program and we have a lot of challenges, but given where we were a year ago, we are light-years ahead today.

Mr. ROEMER. Do you feel that we are light-years ahead given the internal changes in Russia and what they can do in terms of performance in this joint venture?

Mr. GOLDIN. So far they have been performing, but at the direction and insistence of Mr. Sensenbrenner, we have taken some very important actions so that Russia is not on the critical path, and we work—are working contingency plans. We want Russia to be successful but we have an obligation to this Nation to deliver the space station and we will deliver it one way or another.

Mr. ROEMER. Let me ask one more question because I—I am delighted you are up here, Mr. Goldin. I wish you were up here more often so that we could have these exchanges.

The budget goes down by 3 percent in 1997, 5 percent in 1998, 7 percent in 1999, and 9 percent in the year 2000. The NASA budget is on that slide pattern. Shouldn't anything be cut now? Can you be specific on what we can cut now rather than starting six new programs that certainly would have to be cut after 1997 given those cuts?

Mr. GOLDIN. Could I answer that question?

Mr. SENSENBRENNER. Yes.

Mr. GOLDIN. Don't let NASA off the hook. The easy thing to do is to cut programs. With the stroke of a pen, we could cancel the space station and save $10 billion. If we did that two years ago, we would have lost a $20 billion cut that we already had. We have got to restructure this agency and if we don't do anything else, we must look at that first and then look at cutting programs. Don't let us off the hook.

Mr. SENSENBRENNER. Time of the gentleman has expired. The gentleman from Kansas, Mr. Tiahrt.

Mr. TIAHRT. Thank you, Mr. Chairman.

Mr. Goldin, we talked a little bit about the functional cargo block and your relationship with Russia and how they are providing some hardware. Have there been other countries that have bid on providing hardware for the space station in the last two or three years?

Mr. GOLDIN. I don't know of any. Let me ask.

Mr. TIAHRT. Have we tried to develop some relationships?

Mr. GOLDIN. Yes, I take it back. The Italians are providing hardware on a bilateral basis to the payload logistics model.

Mr. TIAHRT. Has there been an effort on our part to coordinate activities with other countries where they would provide hardware or some type of—not only hardware support but also financial support with the space station work? There is a lot at stake here for the entire scientific community, not just the American scientific community.

Mr. GOLDIN. Well, the Japanese are supplying the Japanese experiment module, of which we get 50 percent utilization. The Europeans are supplying the Columbus module of which we get 50 percent utilization, and the Canadians are supplying the robotic arm which will allow us to assemble a space station. If you add up those contributions by themselves, I think it adds up to the equivalent of $9 billion for the development phase, in addition to which we are negotiating with each of these partners for what is called current operating costs and fair charges to launch their equipment up to the space station on board the space shuttle. That is another area where we are looking at for revenues to support this scientific endeavor.

Mr. TIAHRT. So if we were to cancel a program like this, there would be something at stake for the international community, rather than just a budgetary move on our part here in Washington?

Mr. GOLDIN. It will be devastating to the relations between the United States and our international partners after all the money they have invested and the trust they have placed in the United States, and I would say the possibilities for international cooperation in space and other fields will have a major, major problem.

Mr. TIAHRT. Thank you, Mr. Goldin.

Mr. Calhoun-Senghor, is it?

Mr. CALHOUN-SENGHOR. Yes.

Mr. TIAHRT. In your testimony here, the Office of Air and Space Commercialization is developing major policy initiatives and you are working with private sector and other agencies, both at the State and Federal level. What private sector companies have you been working with to develop policy?

Mr. CALHOUN-SENGHOR. Well, first, Congressman, there are, I guess, four areas that we work in in terms of broad policy and then I can get specifically to each one of those.

In terms of the priorities for this year for the office, remote sensing, commercial remote sensing, of which this committee played a very large role in terms of the Remote Sensing Act and putting the licensing responsibility inside the Department of Commerce at NOAA was extremely important.

There have been four—six licenses, four companies, Lockheed, Eyeglass, which is a consortium, with Local Sciences, with I-Tech and GE, Ball Aerospace and World View. We work very closely with them in terms of remote sensing policy, as we do with the State Department, DOD and Intel in terms of developing that.

Mr. TIAHRT. Excuse me. Have you developed a technology transfer policy for taking a technology that is developed under government contracts and making it available to commercial—to businesses, the corporate world?

Mr. CALHOUN-SENGHOR. In our particular office, that is not a responsibility that we have. We do work—in the technology administration, there are people who work with—for example, with NIST in terms of tech transfer. They work with other agencies in terms of Federal technology transfer. Our office is primarily policy related with commercial space. Broad tech transfer, we do deal with to the extent it deals with commercial space, but not as such. But we do work with other agencies, other bureaus within the department that deal with that.

Mr. TIAHRT. You have access to some policy that deals with technology transfer that you are aware of?

Mr. CALHOUN-SENGHOR. Well, in terms of the kinds of issues that we have dealt with, it has not been an extremely visible issue. If there is something specifically, I can get back to you if you had a particular question.

Mr. TIAHRT. I was thinking of remote sensing, if we are going to develop a policy that will develop these capabilities and hopefully transfer them to the private sector so that they can use it to create a profit.

Mr. CALHOUN-SENGHOR. I see.

Mr. TIAHRT. Create jobs. So I wonder, was there some sort of guidelines you are working with to transfer this technology to the private sector?

Mr. CALHOUN-SENGHOR. Ironically, Congressman, I think in this particular case, the private sector is fairly far ahead. What we are trying to do is essentially move out of the way in terms of allowing for the private sector to enter the commercial remote sensing market.

This committee passed a bill which allowed that, created that industry and the President's policy implemented that in a way I think that balanced commercial and defense and intelligence needs. Therefore, it wasn't a case where we had the technology, were transferring it. Many of those companies already were involved in that area.

Mr. TIAHRT. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The time of the gentleman has expired. The gentleman from Minnesota, Mr. Luther.

Mr. LUTHER. Thank you very much, Mr. Chairman, and I certainly want to thank you. I am a new Member of Congress so this has been very informative to me.

I want to just say that, Mr. Goldin, it seems to me that the—what I hear you saying in terms of focusing on the infrastructure of the agency, that that strikes me as making a lot of sense, and I guess I would just ask you if you could elaborate a little more for us on what you mean by restructuring, what kind of a process you are going to go through to make sure that we get the job done. Because of course it is the details that are oftentimes the difficult part of that kind of an effort.

Mr. GOLDIN. We have four teams set up, two teams internal, two teams external. We have a zero-based review team that is responsible for the entire effort, and because the shuttle is so key from a safety standpoint, we have what is called a functional review team.

On the outside, we have asked Chris Kraft, who was the director of NASA Johnson during the key days of Apollo to oversee a task force made up of people from industry and academia to make sure we are not making any wrong decisions, and then the President appointed Dr. John Foster to head what is called the laboratory review, to take an objective look at our laboratories with a team made up of people from academia and industry. And we will have a process going on through May 17th to try and decide what to do, and I want to come back and emphasize again, we have not made any cuts. The shuttle program remains as it was when I testified here last year. We have not taken money out of it.

We will go through this analysis, come up with the results, make recommendations and then take appropriate action. If we could meet the $5 billion cut through infrastructure cuts, then we will do it. If not, we will cut programs. In my testimony, I listed seven basic objectives of the infrastructure review, and for the sake of time, I won't read them here, but these are the guidelines that we are asking the people to look at.

We also told the people, don't come back and just say, give me a budget cut. We are looking for revolutionary change. Don't protect your center. Don't protect a job. You have to objectively look at the overall process, and then we will allow adequate time, and in fact, today I just put in a hiring freeze because I felt it was inappropriate when we are facing the potential for more than just buyouts, that we should be hiring people into the agency.

We have gone for a second buyout so the employees could make voluntary decisions to leave the agency because we have a serious condition, but we have not taken any action to cut the budget and that is why I say we need stability in the budget in '95 and '96 and I have committed to the Chairman that we will not take action without consulting with the committee first.

Mr. LUTHER. If I can just follow up on that. When you do get to the point of looking at the various programs, which I assume also enters into looking at the infrastructure that relate to the programs, how—what process do you use for the quantifying of the benefits or potential benefits from various programs?

I realize that gets into, I am sure, a very difficult area, but what kind of a process do you use on that?

Mr. GOLDIN. Let me give you one example, and if I could have a chart here, it is in your package, I think it is the next to the last chart. Here are three measurables that were used for the scientific program. We take a look at the average development cost of the spacecraft, the average development time, and how many launches we have per year.

And if you look at here from '90 to '94, we had an average development cost of $590 million, we had eight-year average development time, and we had only two launches a year.

If you look in the fiscal 2000 planning period, we project $85 million a spacecraft, three years average development time, and 12 launches a year. I would say that that is a very good measure of output, the number of launches per year, assuming that we have fundamental similar capacity in the basic spacecraft.

I have asked Dr. France Cordova, the chief scientist of NASA, to take a look at objective measurements of scientific output and technological progress that we could factor into this process. So we are developing a matrix as we go. We have gone to the National Academy of Engineering and Sciences to ask for help in this process. It is very complicated.

We used to measure the vitality of an agency by how many dollars it got us in input and if the dollars went down, everyone would get all hot and sweaty. Now measure us by what we do as output. The American people want us cut and we will cut.

Mr. SENSENBRENNER. The time of the gentleman has expired. The gentleman from Florida, Mr. Foley.

Mr. FOLEY. Thank you very much, Mr. Chairman.

I just had a quick question, Mr. Goldin, regarding NASA. What do you have in the way of the structure to encourage NASA's acquisition of technology from the private sector? It seems a lot of the materials I have read, unless NASA makes it itself, it is not good enough, and there is a lot of things you may spin off to the private sector. But what do you spin on from outside contractors to the NASA program?

Mr. GOLDIN. Let me give you a perfect example. When we started this process, and I take back the fact that we took no action. We took one action, which I do have to report. The NASA chief financial officer took a look at a program called NAFIS. It was a NASA financial system that has been in the making since 1988 and it looked like we were going to approach completion at sometime in the 22nd Century.

We were using custom software for a financial system developed in-house by NASA to control how we would manage ourselves so that the NASA chief financial officer canceled that and said we are going to go out and get a commercial product; and by edict, no one in NASA in the financial management system will develop custom software again because there is much better software that exists in the commercial domain.

We are giving those instructions to all our people, and on a number of our programs, the Lewis and Clark mission is a perfect one. We went out with a RFP which simply said, NASA will have no more than two to four people managing this program. We want the most exciting, boldest ideas we could get from industry. Tell us how this will generate new economic opportunity while doing the scientific mission, how you will bring schools into it so children could be part of the process, and we got two proposals, one for $59 million and one for $49 million to design, develop, build, launch, and operate spacecraft in orbit for one year.

So for $108 million, we are getting two spacecraft. I will point out that one of them has a hyperspectra sensor with 384 bands as a reference, although it is not a one to one, the Landsat program using 1970s technology, custom developed by NASA is three-quarters of a billion dollars. I submit this is the right way to do things, and the way we save money is getting NASA out of the business.

We tell the industry what we want and why we want it and we tell them, let them tell us how to do it and, in fact, in that RFP we said, you tell us how you want NASA to be the subcontractor. And in the reusable launch vehicle, someone at a press conference asked me, Mr. Goldin, will the cuts that are going to come in NASA Marshall be made up by the reusable launch vehicle? My answer was, I don't know. We will see what the contractors say that they want from help from NASA Marshall and if they ask for help, they will buy them as a subcontractor. If not, there will be no work at NASA Marshall.

So this is how we are going to have a complete change in the way we do business at NASA. It is very painful. I have tremendous regard for the folks at NASA Marshall, but we are going to ask industry how to do it and we went with a cooperative announcement notice instead of a RFP so industry could take the leadership in that activity.

It is very difficult to have change, and we are going to have a lot of concerns about it. But if we want to change the agency, we are going to have to make drastic changes in the processes like that.

Mr. FOLEY. Do you really think that will be successful? I think there will be a cultural war inside NASA to hold on to what they have.

Mr. GOLDIN. You may see me thrown out of the agency because the troops have won out, but I ain't giving up.

Mr. FOLEY. I yield back.

Mr. GOLDIN. I am not saying that I dislike the troops in NASA. There are many people that want to make this happen and employees stop me and say, God, this is exciting.

How it will come out? There are no guarantees but I tell you I am absolutely deeply committed to causing this change to occur, and I went back through congressional testimony. The Congress has been asking for this for years. We will all have to work together because people will have individual constituent needs and everyone is going to have to say, just say no.

Mr. FOLEY. It just seems like in other industries, the pharmaceutical industry, they are all competing with one another to bring the best product to marketplace. It seems like with that input from the outside into government, we would be much more successful and much more cost-effective.

Mr. GOLDIN. I agree with you completely and that is what we are going to try to do.

Mr. FOLEY. I yield back, Mr. Chairman.

Mr. SENSENBRENNER. The time of the gentleman has expired. The gentlelady from California, Ms. Harman.

Ms. HARMAN. Thank you, Mr. Chairman. As I think the witnesses know, and you probably do too, I began my tenure on this subcommittee in 1993 as a doubter of NASA and of the station program, and Mr. Goldin will remember standing sweating in the entry way to the House Floor when I was the last vote for the authorization for station in 1993. Well, I—

Mr. ROEMER. I will never forget it, either.

Ms. HARMAN. That is right. Yes, that was the one vote. Here I am. Well, I have become a fan, both of NASA and of station, sorry, Mr. Roemer, and watching you today, Mr. Goldin, I would say that you are combat ready and I would just like to tick off a few things that have impressed me and then ask you one question.

First of all, I think station is sound and should be reauthorized and we should appropriate the money requested. The most interesting thing you have been able to achieve, in addition to the Russian collaboration, is the 30 percent cut in overhead. I hope that that is mimicked throughout the agency and it is a good target.

Secondly, basic science is funded and I would point out to Mrs. Seastrand that a number of important California programs are funded, AXAF, the X-ray telescope, Cassini, Mars Surveyor, Mission to Planet Earth, TDRSS, and so forth. They are important to California. They are very important to NASA.

Third, the effort to fix the Hubble telescope was fantastic, and I was with you when we watched some home movies taken by a woman astronaut of her efforts in that regard, and it is amazing and the system now works very well and congratulations to you.

And fourthly, commercialization opportunities are being pushed by NASA and I have seen the results in California and they work and it matters.

My message to you would be, keep doing what you are doing but also do it faster. I think what the Chairman has said about the effort here to authorize this program in the right sequence is very important, and my question to you is, what can you do about that May 17th date? I mean, you have had this information about the budget cuts in the out-years for one month. From January 12th to February 13th is one month. How can you, and you are very good at this, escalate this so that we get the information, say, by early April, assuming that is in time?

Mr. GOLDIN. Let me say that we lost a month. I was in shock, and I had to get over an emotional barrier because I knew what was involved in addressing the Nation's—the agency's infrastructure. The people who work for me are going through that same deliberate decision process. I wish I could tell you I was a robot. I know that lives of people are going to be impacted and it is not a very comfortable place to be, but I am now over that emotional hurdle and I am prepared to work on it.

I have been trying to rack my brain because the Chairman has asked a very thoughtful question and we have been sending notes back and forth, and bear with me, towards the end of the hearing, we will try and have an answer. I understand the dilemma that the committee has and we will see if we could do something, but I don't want to make a promise that we can't keep and that is what is giving me concern and my people told me they needed until the 17th.

Ms. HARMAN. What worries me about that, I hear you, is that NASA will be the loser if you can't try to adjust to a schedule that is really required in these times. Thank you.

I yield back, Mr. Chairman.

Mr. SENSENBRENNER. Time of the gentlewoman has expired.

The gentleman from Michigan, Mr. Barcia.

Mr. BARCIA. Thank you very much, Mr. Chairman. I don't think I will take the entire five minutes but I do want to make a few remarks.

And of course, Mr. Goldin, I would like to thank you for the kind invitation that NASA extended to me to visit the most recent shuttle launch. I was amazed at the precision and the professionalism of all of the NASA staff and of course learned a great deal as a result of my experience in actually witnessing the shuttle launch, and also the interaction between the staff, myself. I think gives me a much stronger appreciation of the challenges that you face, and I hope that certainly as we look at a much pared down NASA budget, that we are not penny wise and pound foolish in terms of making some of the cuts, and I have complete confidence in your administration and your leadership with NASA that those good decisions will be made to preserve the research and the programs that have merit and also to—wherever possible, to spare certainly the staff that you are looking at in terms of the major numbers of people that may be displaced as a result of these budget cuts.

I would just like to say, also, that I can appreciate your comment about being in shock. I, too, was in shock as a result of some of the money that was not included in the President's new budget; $27 million has been deleted for the construction of a facility for CIESIN in downtown Saginaw. You know, CIESIN is currently housed on the campus of Saginaw University which is in Congressman Dave Camp's district and I know many people in my district were very anxious that the program would grow, flourish, continue to provide state-of-the-art research, technical capabilities to disseminate information to academicians and policy-makers around the world about the impact of the human population on the earth's natural resources, as well as to use the tremendous base of information that NASA provides through research scientists, especially in this country and around the world.

I would like to just ask you, Mr. Goldin, if at some point in the future you might be able to attempt to visit CIESIN's Washington office to review the research and certainly the status and the quality, I think, of the research which it has been conducting, because we are very proud of what it has accomplished to date and I know that you have assigned top staff at NASA to sort of do a status report on where we are with CIESIN, and I do want to thank you for that and for always the kind and sort of—certainly response and timely response and also the accessibility of yourself and your staff to my office with regard—as well as the Michigan's delegation with regard to our concerns about CIESIN.

I know I am making mostly comments, but if at some point you could personally visit the Washington office, I think any Members of this subcommittee or the full committee, I know that we would appreciate that.

Mr. GOLDIN. I would be pleased to do it.

What we are doing right now with CIESIN, as with every other job, is saying, does it have a benefit to the American people; does it have measurable benefits? And if it does, we are going to support it.

And I do have to say, the President made the decision to cut the facility but the administrator supports the President. We took our facility budget down from roughly a half billion a year down to 160 and I would rather have payment for human beings rather than building temples unto a future.

Mr. BARCIA. Certainly I can appreciate that.

Mr. GOLDIN. And I don't say this in any prejudicial manner relative to the CIESIN activity, but we are going to be very, very tough across all activities.

Mr. BARCIA. Thank you very much, Mr. Chairman.

Mr. GOLDIN. Mr. Chairman, can I make a statement? I would like to take correct that. We took the shuttle flights down from eight a year to seven a year and that saved $100 million a year, but that was a specific action related to a specific task. Other than that, we have not touched the shuttle budget.

Mr. SENSENBRENNER. Thank you.

The gentleman from Florida, Mr. Hastings.

Mr. HASTINGS. I thank you very much, Mr. Chairman, and I want to thank all the witnesses.

Mr. Chairman, you know this is a good argument for us not having term limits. When us new people come on board, the learning curve is so steep, until it probably takes six years to understand what the hell everybody is talking about. But at the very least, I will make a stab at it.

Mr. Weaver, your level of full-time equivalents increased from fiscal year 1994 from 24 to 28 in fiscal year 1995, and your fiscal 1996 increase calls for an additional four. Can you tell us what these additional employees's functions are going to be and whether or not you anticipate any future increases, say, in the next four years?

Mr. WEAVER. Yes, I can. In fiscal-- the increase—the original increase was recommended in order to address the increase in activity in my licensing and safety division. As I indicated to you in my testimony, there are a lot of new launch systems and commercial spaceports that are not the conventional expendable launch vehicles, and they pose an increasing demand upon my staff, which was already understaffed, to meet the existing demand. So that increase from fiscal year 1994 to 1995 was primarily to fund increases in my licensing and safety division.

Also, in 1995, we had five positions added and there are no increases in positions in fiscal year 1996. But the funding level was not adequate in fiscal year 1995 to fund those increases in personnel in FTEs. So the funding that we have requested in 1996 will be primarily to address more FTEs in the licensing and safety division.

We did utilize one of those FTEs in our policy area because of the new emphasis in increasing the commercial competitiveness of the U.S. space transportation industry, and that was where one of the other FTEs has been utilized.

Mr. HASTINGS. Okay. Mr. Calhoun-Senghor, I would appreciate very much, your time permitting, some staff visiting with me so I can understand better the remote sensing information that you talked about and more specifically as it pertains to which other countries are competing in the commercial remote sensing and what the Department of Defense and CIA are saying about that.

I serve on the International Relations Committee and would be interested—I won't bother to ask you for a response right now, but if you would follow up on that, I would appreciate it.

Mr. Goldin, as you well know, I am very much impressed with the extraordinary work that you and all of NASA have done, and including your predecessors in spite of much of the criticism here in the Congress and elsewhere.

I would like to know what impact the proposed budget cuts are going to have on NASA's activities in the field of education, which I know an awful lot of what you have done with reference to minority opportunities in that regard, and I am also very concerned about the personnel makeup of NASA. When you have a second wave of buyouts, how is that going to affect your number of women and minorities in an overall capacity? But I guess I can talk with you about that personally.

What I really would like to know is if we don't do the reusable launch and if we retool the shuttle, what are the implications for science, more specifically research? Because my thinking as a lay person is that the newer vessel that you all are about would be in line with most of the advanced technology that is state of the art as well as anticipating something in the future, whereas the shuttle may not be able to accommodate that kind of research or undertaking, and in that sense, I think we lose, and I am a supporter of going forward is where I am coming from. What are the scientific implications?

Mr. GOLDIN. Well, there are a number of implications. One you heard from Mr. Weaver. America has not developed a new launch system, major launch system, in 25 years. Do we want to sit in the grandstand and watch the world go by? The shuttle is a wonderful machine but we have got to provide the President of the United States information to make a decision.

Now, we could choose to do all sorts of other things in the next five years, but just because the new reusable launch technology is the last in, does it deserve to be the first out? And there is always the temptation, because NASA has constituencies for existing programs, I am not sure, and those constituencies are the American people. They are the people working on it. We have got to do the right thing for the American people.

Mr. HASTINGS. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The time of the gentleman has expired.

The gentleman from Tennessee, Mr. Hilleary.

Mr. HILLEARY. Mr. Chairman, would it be okay if Congressman Rohrabacher and I switched times? He is the Chairman on another committee and needs to get out of here real quick.

Mr. SENSENBRENNER. The gentleman from California, Mr. Rohrabacher.

Mr. HASTINGS. I was tempted to object, Mr. Chairman.

Mr. SENSENBRENNER. The Chair, under the rules, retains the power of recognition.

Mr. ROHRABACHER. Thank you very much, and I apologize for being late. I was hooked up to some medical technology earlier today and it was probably directly as a result of NASA and so thank you very much.

Mr. GOLDIN. You are welcome.

Mr. ROHRABACHER. And I know the fact that I am here also is a measure of frustration to some, so I would like to introduce this for the record, my opening statement, Mr. Chairman.

Mr. SENSENBRENNER. Without objection.

[The prepared statement of Mr. Rohrabacher follows:]

Introductory Statement by Rep. Dana Rohrabacher at House Space & Aeronautics Subcommittee Hearing on NASA Posture, February 13, 1995

First, let me congratulate Chairman Sensenbrenner and the other members of the subcommittee on our first hearing of the new Congress. I also welcome our panel of three top members of the Administration's space policy team.

We're at a period of instability and anxiety in our space program today... what the Chinese call a crisis of change, or "wai chi"... a word made up of the pictograms for danger and opportunity. This crisis has been building for several years, but only recently has everyone agreed that it is really here and is really unavoidable. I guess that's the impact of seeing smaller NASA budgets stretching out to the horizon.

I want to commend my friend Mr. Goldin for his willingness to accept and even pursue change. But let me assure you and all the space policymakers in this Administration that the level of change that Speaker Gingrich and Chairmen Walker and Sensenbrenner and I are talking about is much more basic and fundamental than anything we've yet heard from this Administration.

It's time to move past efficiency and reform and restructuring and even reinvention. We need to transform our space program, creating something very different than what we have today. The issue is not how well or how poorly NASA does what it is doing right now. The issue is what should NASA be doing in the first place... and even what should NASA try to be.

Here's my rough take on what that transformation might look like. In the post-Cold War world, where even foreign policy is about economics, we don't need a government space program that "does space" for us. We need a space policy and a space agency that empower American enterprise to do creative and profitable things in space. In other words, it's time we brought space policy into the mainstream of economic policy. Our space policy should be nothing less than expanding our economy, and indeed our entire civilization, into the space frontier.

That means we in Congress must devise new tax, regulatory and other policies which encourage private enterprise in space, and then redirect NASA to become the kind of research agency for space and aeronautics that N.A.C.A. was for aeronautics before Sputnik and the Apollo Program.

Notice that the whole way we measure success would be radically different. Instead of worrying about (and perhaps over-bureaucratizing) safety for political reasons, a private launch company would be serious about safety for economic reasons. We in Congress would be happy, rather than upset, if new private space companies made huge profits and their payrolls grew by leaps and bounds. And very soon the American people would finally be able to participate directly in this grand adventure. This may seem like a bold dream, but as Ronald Reagan told us... we have every reason to dream great dreams: after all, we're Americans.

Mr. ROHRABACHER. And I want to congratulate you, Mr. Goldin, number one, you have answered my first question of how you are trying to bring the private sector into play in NASA and I think that you are doing a terrific job in doing that and you are taking a very creative approach.

I have two specific areas that I would like to ask you about. As you are well aware, I am deeply involved with reusable launch vehicle programs, and there seems to be some concern that the X-33, which is the SSTO program, might in some way be hurt by—or subsumed even by the X-34 program. Do you plan to keep those two separate programs?

Mr. GOLDIN. Absolutely.

Mr. ROHRABACHER. And will X-33 funds be fenced off from the perhaps cost overruns of X-34 so the X-34 does not drain funds from the X-33 program?

Mr. GOLDIN. If the X-34 has significant overruns, it will be canceled. If the X-33 has significant overruns, it will be canceled.

Mr. ROHRABACHER. Correct, thank you.

In terms of the space station, what have you done to, for example, bring more private—you detailed for us what you would like to do in terms of bringing more private sector involvement into NASA itself, but what about for the space station project?

For example, what steps have been taken to try to ensure that, for example, you might have commercial launch companies providing the logistical supplies and the logistical support once the space station is up, or perhaps having electricity provided by private companies? Have any steps been taken for the space station project like this?

Mr. GOLDIN. Let me say the following. I think we are pretty well committed on the space station through the year 2002 plus one year. That is the contract we have with Boeing.

Let me commit to you here today that we are kicking off an activity to start today to think about the RFP we will issue in the year 2003, but we will have to get ready for that so that we could consider everything going all the way from privatizing the operations on the space station, and you can't privatize until you have experience in a development sense, until you get to that point, to having a single company, to buying services.

We don't know what is going to exist in the year 2003 so all I want to say to you is, everything is on the table. Contractors have come to visit me and when they come to visit me, I say, don't look upon NASA as a place where you go get contracts and then earn profit on those contracts. Look upon NASA as a place where we enable and open up the space frontier.

Mr. ROHRABACHER. Some of those who oppose the space station project, and I will have to say that I don't believe that they are totally irrational in their opposition to the space station project. Mr. Roemer and others have presented their case very well, but quite often, I see those who oppose the space station project as seeing the space station as an end in itself. Others of us who have supported the space station see it as a first step, perhaps as being a—the center of a hub of private sector activity in space in the next century.

Mr. GOLDIN. We want to make that happen and we will see how far we could go with the industry, but we put a sunset clause on the space station at 2012, and as part of the redesigned program asking for a national review to see if the space station did what it said it would do, is it possible to turn it over to commercial companies, and if we could turn it over sooner, we will, and if we can't, shut it down.

Mr. ROHRABACHER. Or at least to have commercial companies operating private sector space facilities near the space station.

Mr. GOLDIN. If they are willing to step up. We just don't know whether they will or not.

Mr. ROHRABACHER. And do you see anything that Congress can do in terms of passing laws that will facilitate the commercialization of space that may in some way take some of the burden off NASA?

Mr. GOLDIN. Mr. Sensenbrenner had a meeting with us just a week ago and he has asked before your markup that we get to him some recommendations along those lines and we intend to do just that.

Mr. ROHRABACHER. I am sorry if some of my questions were repetitive of some of the questions that were said earlier but as I say, I was at the hospital, and thank you very much.

Mr. SENSENBRENNER. The gentleman's time is expired.

The gentleman from Tennessee, Mr. Hilleary.

Mr. HILLEARY. Thank you, Mr. Chairman.

Mr. Goldin, you are aware that the—last year the NASA budget had a $400 million appropriation for the wind tunnel complex and with the stipulation that we had to have another $400 million or that money—original $400 million went away. I notice that yours does not. Your next year's budget does not have the additional $400 million, and when I talked to you the last time in the full Science Committee, you indicated you really thought this was an important project, and I was wondering, do you think this effectively kills the project, certainly for the near term?

Mr. GOLDIN. Let me say this. If you looked at the wording of the President's budget, it asks that we not be obliged to add another $400 million in budget authority in fiscal 1996, that we felt that that $400 million in budget authority but zero outlay authority was appropriate. We do not want to make any commitments on the space station until mid 1996 when we will have completed the site selection study. We will have had an idea about the environmental impact reports that we have to file, the real costs for it, and give the industry a chance to get a turnaround, because the orders for long haul jet transports are pretty low right now, so if the industry had a chance for turnaround, they could make a more substantial contribution.

So it is our desire not to make it—and then we would know where the NASA budget was at that point in time. So it was our desire to continue the ongoing study that is industry led. It is led by—it is a Boeing-led team with McDonnell Douglas and Pratt Whitney and GE and I think Northrop and Lockheed on it.

So our desires are to leave it alone, because that $400 million just is not in outlays and not make the decision until fiscal '96. So we would like to continue on the path that we are on.

Mr. HILLEARY. You certainly did include requests that legislation be enacted to extend the availability of that original 400 to keep the original 400 fenced off. We could have done that without your suggestion or your request, but what—the action that you took effectively, if we do nothing else here, effectively killed that original $400 million, if I am not correct.

Mr. GOLDIN. We are requesting the Congress to approve what we submitted.

Mr. HILLEARY. Well—

Mr. GOLDIN. And we are prepared to work with the Congress to do just that.

Mr. HILLEARY. Well, do you think—how do you think, if—assuming the wind tunnel project came along, how would that affect our competitiveness with the European consortium? Simply, I don't know if you are aware of this but this last month for the first time, more airplanes were bought from European countries than domestic companies and I think that probably is part and parcel to us losing our competitive edge and this surely would enhance that; would it not?

Mr. GOLDIN. In the last—I think in the last 40 years we have built one new wind tunnel in this country. We want to make the competitive aspect another part of the study. We would like to have the data, so rather than shooting from the hip, we could deal with it directly. But we are going to have to have a different arrangement on those wind tunnels. It is not just going to be a government-funded program, and we want to give the industry a chance to really understand how much it is going to cost. So we would really like to have the support of the Congress to continue the study. Unless we do the study, we won't have the results.

We have lost 1 percent market share per year for the last 25 years and we are now down to 65 percent and we are on a curve that will take us below 50 percent at the turn of the century. This is not going to be—do you want to fly on planes that have no American flags on them?

Mr. HILLEARY. That is the problem, and I guess what bothers me more than anything else is that our mandate in the freshmen class was not to shut down the Federal Government, not to have no more Federal expenditures, but to make the ones that we have more practical, more common sense, and it seems to me that—I am fascinated by this committee and the work that we do and NASA and space flight and space in general.

I am fascinated but I am not sure my mandate was to maximize my fascination. I think it was to maximize practicality, and when we are talking about the aeronautics industry and losing our competitive edge, losing jobs, losing orders, that is bread and butter, that is meat and potatoes, and I guess I am concerned that some of these other projects that you do seem to be pushing pretty hard are more—instead of meat and potatoes, they are more like the sugary desserts that voters asked us to maybe not pursue quite as hard as we have in the past and I would enjoy your comments. Thank you.

Mr. GOLDIN. My comment is this: For too long we have shot from the hip and didn't know how much things were going to cost and then we sit here debating overrun. We really need to understand how much these wind tunnels are going to cost, and although we have an estimate right now, we are going to be moving around hundreds of megawatts, huge amounts of water, large pieces of steel, and we just don't really understand it.

We need to get industry to look at us as not the place where we subsidize everything in the government. We need a new relationship with industry. We need this time until mid 1996 to understand it, and that is what I really ask for and we are going to oppose the rescission that just came up in the House.

Mr. HILLEARY. Thank you very much.

Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentleman from Texas, Mr. Stockman.

Mr. STOCKMAN. Thank you, Mr. Chairman. I have a question for Mr. Weaver and Mr. Calhoun. Could you tell me how your—I guess we are in a situation now we are trying to—where we have been talking about and this is an honest question; I am a little confused. We are trying to cut back on duplication, and could you tell me how your job is different than what Mr. Goldin's job is?

Mr. WEAVER. Yes, I can. As I had mentioned in some of my earlier comments, for the national space transportation policy, we are to, along with the Department of Commerce, help develop these public sector, private sector partnerships. The development of, for instance, reusable launch vehicles is being undertaken by NASA to define the technology. We are to develop public-private partnerships that will bring industry on board to assist in the development and have industry cooperate in getting them built.

Then once the technology is proven, we work with industry to, one, regulate these new vehicles for safety because we are the only agency within the Federal Government that has regulatory responsibility for safety, and then also to make sure that we drop the cost of access to space so that the benefits of satellite systems can then be provided at a lower cost and we can retain or restore the U.S. launch industry to leadership. So that is how we cooperate with NASA in the development of those programs, as well as the Department of Defense.

Mr. STOCKMAN. Couldn't vast sums of money, though, be saved if we consolidated it into one agency?

Mr. WEAVER. In trying to accomplish both missions?

Mr. STOCKMAN. I mean, to me it seems a little bit of a duplicated effort, but I am going to let that go and maybe I can get at a further date some more information, but to me it almost makes sense to have NASA do your role, but forgive me. Maybe I need the Chairman to fill me in on that at some point.

Mr. WEAVER. If I may, the role and responsibility we have at the Department of Transportation is first and foremost to protect the public safety. That is not a mission of NASA, and the Department of Transportation is a regulatory agency and that is our primary responsibility.

Mr. STOCKMAN. I thought we were putting a moratorium on all regulations, Mr. Chairman.

Mr. SENSENBRENNER. If the gentleman will yield, that is the function of another committee.

Mr. STOCKMAN. Okay. Mr. Goldin, when you were before the full committee, you told me you would have—in your testimony, that you would have numbers on the number of cuts back then and we met privately and you told me they were embargoed, and, quite frankly, I think that—I know now that you are saying later you are going to have the numbers. Isn't there targets or something that you are shooting for that we can have now?

Mr. GOLDIN. The only data we do have, and I can give it to you, is we took an initial target on the buyout.

Do we know the initial target on the buyout? Do we have that?

Okay, what has happened is, since the time we set forward, we have been looking at the impact of this big cut and the more we look at it, the more we don't know. We can give you the initial allocation of the buyout for NASA Johnson. My recollection is it was about 250 people. Is that right, Sam?

Where it is going to go now, I don't know. We are going through the zero-based review. We are looking at major changes. We don't even know where the review is going to go. So I can't answer other than our initial estimate is 250. Beyond that—

Mr. STOCKMAN. Did you say May 17th is when you were going to have it? Do you think that those numbers will be more firm then?

Mr. GOLDIN. Oh, yes.

Mr. CALHOUN-SENGHOR. Congressman, if I may just respond to your first question because I think it is a relevant question, but I think there are a couple of very simple and important answers.

First of all, is that our office, and I will speak directly to mine, is involved and concerned with commercial space. That is different than civil space. That is to say, government space programs by themselves have historically been different and pursued different means than a commercial, a private sector space program. And we have, in our office, four people, a budget of $450,000. I don't think we are going to balance very many budgets off of that and I think, frankly, we are a paradigm of what we are trying to have in terms of reinventing government.

We have a central office that works with other departments, that works within the Commerce Department, which is a commercial agency, to advance the interests of commercial space. That is often not always at odds with a civil space—

Mr. STOCKMAN. I don't disagree with your purpose. I was just wondering if, for efficiency, we could roll it—

Mr. SENSENBRENNER. The time of the gentleman has expired.

Mr. STOCKMAN. Can I finish this one last question? How many employees were requested to participate in the buyout? Do you know?

Mr. GOLDIN. As of the close of last week, for the whole of NASA, I think it was 659, 57.

Mr. SENSENBRENNER. The gentlewoman from Texas, Ms. Jackson Lee.

Ms. JACKSON LEE. Mr. Chairman, thank you very much and, Mr. Goldin, and other members of the panel. Thank you for accepting the apology that I am going to offer, having been at another meeting with constituents that I couldn't depart from.

But I appreciate your presence here on an important matter for our hearing and, Mr. Goldin, I will ask you to conclude my questions by answering at the end of a series of questions that I am going to ask, is a discussion that we had when you were previously here, at least a point that was raised where we discussed this concept of a flat budget, and I had a great deal of interest in that as we proceed to try to budget you this year, whether we are creating policy for one year or should we really be looking at policy for over a five-year period inasmuch as what we are trying to get NASA to do.

But let me focus on the whole idea of space travel, focus in particular on the space station, and try to highlight that particular budget to find out what percentage of the space station budget is targeted and does that percentage, whatever it might be, which you will share with me, have an impact on the programmatic aspects of the space station, which would include schedules, safety, staff, and the quality of the program? Why don't I let you start with that and then I have one or two others.

Mr. GOLDIN. The answer is, the space station was not targeted for any cuts, so we are not planning to cut from the space station budget. However, if we do find some savings, we will certainly take them. It is my expectation that for the development phase, we are going to hold tight. Any money we find, we are going to put into reserve.

Mr. Weldon asked us a question about maintaining reserves—you moved, I am sorry—he asked us the issue of do you set aside reserves against potential problems. So any savings we find in the development phase of the space station go right into reserves.

Secondly, we will look at the operations phase, as I discussed with Mr. Rohrabacher, looking at ways to do it more efficiently, all the way up to seeing if we could commercialize it and get companies to take over and to bring in industry.

One of the problems we have, and I challenge the folks down at NASA Kennedy, is to cut the cycle time for processing payloads, because this is the single biggest impediment that we believe we have to getting private corporations to use the space shuttle and the space station.

So we do believe we could get some savings in the operations but we are looking at savings in the operations budget once we complete development.

Ms. JACKSON LEE. And certainly a follow-up question I was going to have is, regardless of where we go with the space station, we will be seeking to be efficient and effective with the dollars that we utilize for the programs. So the fact that we are utilizing and not cutting the dollars and we need the dollars that we have, we are still going to be efficient and effective with what we have.

Mr. GOLDIN. And let me tell you, it is my hope that two or three years from now when we get through the key part of development, if we have reserves to turn back to the government, we will turn them back to the government. It will not be like the end of the fiscal year where people go running to spend money because they are going to lose it. We have an obligation to turn back money, if we can.

Ms. JACKSON LEE. Thank you.

Correct me if I am wrong, I believe the NASA contract dealing with this is with Boeing. That was just issued, am I correct on that? And one of the aspects of—I think the rendering of the contract was the whole idea of cutting bureaucracy. Do you have some kind of read or how that is going to work in the Boeing contract in the cutting bureaucracy aspect of it?

Mr. GOLDIN. Well, we put a very nice clause into the Boeing contract. If they underrun, they make more profit. So we are incentivizing them to turn back money.

On the other side, if they overrun, they are going to lose a disproportional amount of profit and very rapidly have no profit. We have asked them to flow down that clause to their contractors. The other thing we have told them is on incentive fee and award fee, you don't earn it. You can collect the money but you don't earn it until it works on orbit.

So we tried to set up a very commercial like set of conditions which gets the government out of telling them how to cut bureaucracy and motivate them with profits. If you get bureaucracy out, you make more profits. You overrun and are bureaucratic, we take it away.

Ms. JACKSON LEE. It is a good incentive and I would hope, you don't have to answer this, that we have in place a very effective monitoring procedure to ensure that that be the case. The incentives are obviously good. I think we need to be a partnership in that. And I say we, both Kennedy and certainly Johnson, to ensure that that occurs, and I would just offer that to you, and I am going quickly because I want to focus on the recommendation that I understand may have occurred a couple of years ago which dealt with—

Mr. SENSENBRENNER. The time of the gentlewoman has expired.

Ms. JACKSON LEE. If I may finish my question, Mr. Chairman, I would appreciate it.

—deals with the centers of excellence, and that was recommended just a couple of years ago as to improve, if you will—to reduce waste and other type activities along with the multiple centers that we have. Can you just briefly give me whether that concept is still alive and have we moved forward on that?

Mr. GOLDIN. We moved forward. It is part of the zero-based review.

Ms. JACKSON LEE. And I would appreciate getting back with you on the zero—the flat budget that we had discussed previously.

Thank you, Mr. Chairman, very much.

Mr. SENSENBRENNER. Thank you very much.

I would like to thank each of our three witnesses. The one who was at bat most, as well as the two that were kind of sitting on the sidelines. We will get back to you later. This part of the hearing is adjourned.

Now, I would like to announce to the Members of the committee, as well as to those who are present, that later on this week we will have two informal briefings relative to various parts of the NASA budget. On Wednesday, February 15th at 1:30 in this room, the subcommittee will have an informal briefing on the following issues, space science, Mission to Planet Earth, and aeronautics.

On Thursday, February 16th, also in this room, at 10 o'clock in the morning, NASA will be finishing up with the following issues: The reusable launch vehicles, space shuttle, space station, and life and microgravity sciences.

These briefings are primarily for the benefit of Members of the subcommittee and their legislative assistants on various issues within the NASA budget. They will not be formal hearings in that we will not have court reporters and five-minute rules and things like that. But it is designed to be somewhat of a dialogue, particularly for those Members who are new to the subcommittee on this very complicated issue.

So I would encourage Members of the subcommittee to come. If you cannot come, I will be glad to recognize designated legislative assistants, one per Member, to ask questions of the NASA associate administrators, but following recognition of all of the Members who are present. So without any further comments, this hearing is adjourned.

[Whereupon, at 2:19 p.m., the subcommittee was adjourned.]

FISCAL YEAR 1996 NASA AUTHORIZATION

THURSDAY, MARCH 16, 1995

House of Representatives,
Committee on Science,
Subcommittee on Space and Aeronautics,
Washington, D.C.

The Subcommittee met at 8:06 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable F. James Sensenbrenner, Jr., Chairman of the Subcommittee, presiding.

Mr. Sensenbrenner. The Subcommittee on Space and Aeronautics will come to order.

Let me welcome you all and thank you for appearing at this early hour in the morning and also for postponing or rearranging your schedules after the session of the House on Monday collapsed and we didn't have enough people to conduct the hearing.

Without objection, I am going to include my opening statement and the opening statement of the gentleman from Texas, Mr. Hall, in the record so that we can get going right away.

[The prepared statement of Mr. Hall follows.]

OPENING STATEMENT
of
HON. RALPH M. HALL

March 16, 1995

Good morning. In view of the large number of witnesses that have been asked to testify today, I will be brief in my opening statement.

As we all know, Members of Congress will be faced with a number of important decisions this year on the future direction of NASA and the nation's space program. I remain a strong supporter of the space program and believe that the commitment our taxpayers have made in the space program have delivered substantial benefits to all of our citizens. And I'm excited about the benefits that the space program will deliver in the future. Projects like SOFIA, space-based biomedical research on the space station, and other planned activities too numerous to mention all convince me that we have much to look forward to in the coming years.

In considering our future commitment to NASA, we shouldn't forget that this nation has made a significant investment over the last 35 years to build our capability to explore space and return the benefits of that exploration back to the taxpayers here on Earth. We must be careful that we don't do anything "pennywise and pound foolish" that could inadvertently weaken what the United States has worked so hard to develop.

Finally, I'd like to express my appreciation to Chairman Sensenbrenner for calling this hearing. I am gratified that he is continuing the Space Subcommittee's tradition of seeking outside testimony on NASA's programs. A significant number of the witnesses here today have appeared before the Subcommittee on previous occasions, and we always value their opinions.

Mr. SENSENBRENNER. The ground rules for this hearing will be that each witness will have no more than five minutes in order to summarize their written statements. And, please do not read from your written statement, because we have got them all and we are reviewing them and can read and see what your points are.

So, just summarize the high points of that in five minutes or less. The Chair will also strictly enforce the five minute rule for questions from members of the Committee when they appear.

So, without objection, all of the written testimony of all of the witnesses today will be included in the record.

The first panel will be on the subject of restructuring of NASA. We have four witnesses. David Moore, Senior Analyst of the Congressional Budget Office; Wolfgang Demisch of Bankers Trust in New York City; Rick Tumlinson, President of the Space Frontier Foundation in New York City; and, Gerald May, Assistant Director of the National Legislative Commission of The American Legion in Washington.

Mr. Moore, you are first and recognized for five minutes.

STATEMENT OF DAVID H. MOORE, PRINCIPAL ANALYST, NATURAL RESOURCES AND COMMERCE DIVISION, CONGRESSIONAL BUDGET OFFICE.

Mr. MOORE. Mr. Chairman, I appreciate this opportunity to testify on the National Aeronautics and Space Agency's (NASA) efforts to restructure and its continuing effort to adapt to lower budgets.

The five year plan consistent with the President's request for 1996 requires the agency to make unspecified reductions of 4 billion dollars for the period 1997 through 2000. This cut comes on the heels of much larger ones indicated by the plans for 1994 and 1995.

Under the 1996 plan, NASA's budget would be 13.2 billion dollars in the year 2000, 9 percent less than its current level without adjusting for inflation and almost 25 percent less than its current level after such adjustment. NASA has not specified how it will close the gap.

The space agency, no doubt, will continue to carry out the reforms it initiated in 1993. The Congressional Budget Office's (CBO) 1994 study of NASA's effort to change the way it does business concluded that those reforms, while worthwhile, were unlikely to produce sufficient cost reductions to allow the agency to avoid further reductions in its program.

It's still too soon to say whether reforms will allow the agency to buy more for less. An encouraging sign is improvement in program cost and schedule estimation.

However, NASA is counting on efficiency gains to make the budget plan it currently operates under work. The tougher choices of downsizing the institution and the program now remain if NASA is to live within its budget.

Some people suggest that NASA approach its problem the same way that private sector firms have when forced to downsize. The agency's current effort to adjust to lower budgets emphasizes reduction in personnel and the institution so that program can be saved.

That approach is analogous to a private sector entity's effort to restructure by reducing the resources devoted to middle management and eliminating redundant functions and facilities. Successfully adapting this approach will require NASA to make larger than proportional reductions in overhead and management functions.

To date, by the imperfect measures available, the agency has not made such reductions. For example, in 1995, the agency spent 2.2 billion dollars in its research and program management R&PM category, covering civil service salaries and funding for NASA administrative functions. That was 15.1 percent of its budget. It's down only slightly from 16.4 percent in 1990.

What would larger than proportional reductions in overhead look like in the current situation? Absorbing half of the 4 billion dollar reduction in the research and program accounts would lower the R&PM share to a little over 12 percent of the agency's proposed budget in the year 2000.

If the entire reduction were taken from overhead, the R&PM share would be about 6 percent at that time.

Some people might question whether NASA could maintain the scope of its current program with a federal work force that would be only half of its current size. Reducing research and program management to the levels just discussed might hurt the agency's technical competence, diminishing both healthy competition of ideas and approaches within the agency and its ability to be an intelligent buyer from the private sector.

From this perspective, it may be preferable, even imperative, to reduce the agency's scope of activities as well as downsize its overhead.

NASA could reduce its budget by narrowing its focus. That approach is analogous to another widely used strategy in the private sector that achieves cost savings by selling off lines of business and the facilities that go with them. Improved performance is realized by concentrating the remaining assets of the firm on fewer markets.

CBO's 1994 report developed three alternative programs that each focused on a specific part of NASA's current "product line"—one that emphasized human space flight, another that emphasized space science but maintained human space flight as a complement, and a third that emphasized space science and technology but eliminated human space flight.

Narrowing the product line offers an advantage compared with across-the-board reductions. It forces the Congress and the agency to decide what is NASA's best mission at a time when resources are constrained.

A more narrowly defined mission will permit the agency to make better choices about what should be kept and what must be abandoned when faced with the prospect of additional large cuts in the federal work force and perhaps closing major NASA field centers. Ultimately, such an approach may provide taxpayers with the highest return for their investment in the civilian space program.

Thank you.

[The prepared statement of Mr. Moore follows.]

CBO TESTIMONY

Statement of
David H. Moore
Principal Analyst
Natural Resources and Commerce Division
Congressional Budget Office

on
Restructuring NASA

before the
Subcommittee on Space and Aeronautics
Committee on Science
U.S. House of Representatives

March 16, 1995

NOTICE

This statement is not available for public release until it is delivered at 8:00 a.m. (EST), Thursday, March 16, 1995.

CONGRESSIONAL BUDGET OFFICE
SECOND AND D STREETS, S.W.
WASHINGTON, D.C. 20515

Mr. Chairman and Members of the Subcommittee, I appreciate this opportunity to discuss restructuring the National Aeronautics and Space Administration (NASA) and the agency's continuing effort to adapt to lower budgets. The Congressional Budget Office (CBO) presented testimony to this Subcommittee in October 1993 and released a related study, *Reinventing NASA,* in March 1994, both of which respond to the questions before the Subcommittee today. CBO's last look at NASA reached two conclusions:

- Changing the way that NASA does business may offer improved program management and technical performance and some cost reductions, but the associated budgetary savings are uncertain and unlikely to be realized in the near term.

- Canceling, scaling back, or stretching out programs and reducing NASA's federal workforce are necessary to lower the cost of NASA's program to the level included in the President's 1994 budget plan. Cost reductions created by more efficient management, procurement, and acquisition practices are unlikely to be large enough to allow NASA's budget to be cut further without additional reductions in its program. Ultimately, a smaller budget will mean a smaller program and fewer accomplishments for the civilian space program.

The five-year plan consistent with the President's budget for 1996 requires the agency to make unspecified reductions of slightly more than $4 billion for 1997 through 2000. The agency is faced with the unenviable choice of reducing its current program, trimming its institutional capability (including the civilian workforce), dramatically narrowing its focus, or some mix of the three. The conclusion CBO reached 18 months ago seems more pertinent than ever: ultimately, a smaller budget will mean a smaller program and fewer accomplishments for the civilian space program.

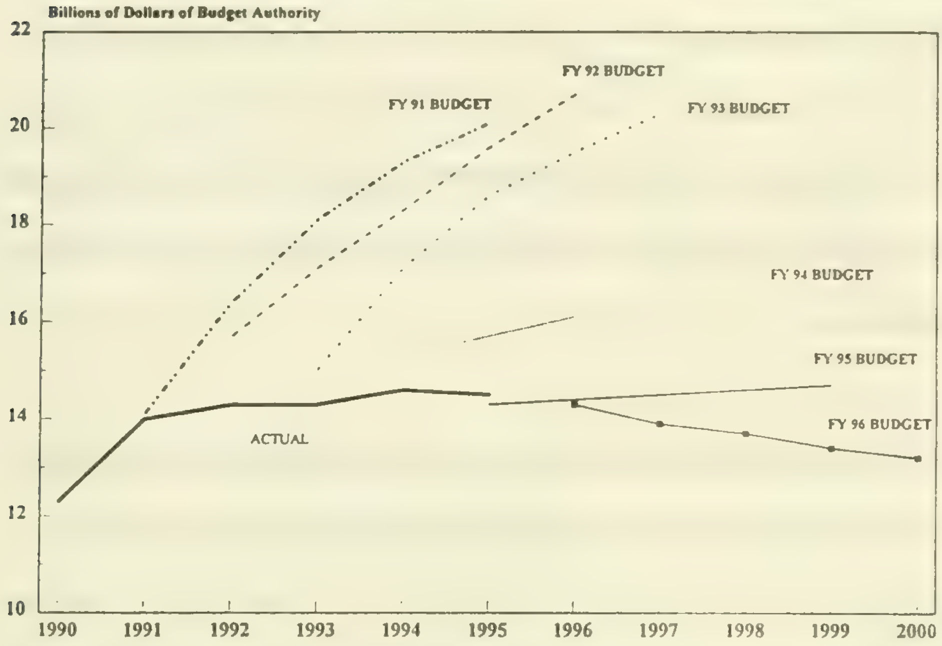
Absorbing a large part of the $4 billion reduction may be possible by decreasing NASA's civilian workforce and other costs carried in the agency's institutional accounts (largely captured in the accounts known as research and program management). One might question, however, whether maintaining the current program's scope with reduced overhead delivers the most benefit to the taxpayer. An alternative approach would be to adopt a strategy that narrows the agency's mission, or product line (to use the language of the private sector), based on a clear understanding of which activities produce the greatest benefit for their cost. That approach may capture even greater saving than those required by the President's request for 1996. NASA might be called on to make such larger reductions should the Congress devise an overall budget plan that reduces the deficit more than the President's budget proposal does.

BACKGROUND

The current demand to reduce NASA's planned spending is only the most recent in a series of reductions that have bedeviled NASA's management since 1993. Since 1991, the space agency's budget has been essentially flat, inching up from $14.0 billion to $14.3 billion (see Figure 1). Before the 1994 budget plan, however, NASA's budget plans for 1991 through 1993 proposed programs that would have driven the agency's budget above $20 billion annually. NASA's five-year plan accompanying the agency's 1994 request began the process of deflating those expectations. That plan called for $16 billion less than what the agency anticipated in the 1993 plan. The five-year plan submitted with the President's request for 1995 required further cuts of about $10 billion.

Compared with the previous two budget exercises, the five-year plan that was to accompany the President's 1996 request for NASA required only minor adjustments--reductions of $405 million from 1996 through 2000. In January, however, NASA and other agencies were directed to make additional reductions. Specifically, the agency was asked to freeze its budget at the level of funding requested for 1996--$14.3 billion--and make increasingly larger reductions from that level for each year from 1997 through 2000. In that final version of the President's 1996 request, NASA would be funded at $13.2 billion in 2000, a decrease of 9 percent from the 1995 level before adjusting for inflation, but almost 25 percent after

FIGURE 1. FIVE-YEAR BUDGET REQUESTS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, 1990-1996 (By fiscal year)



SOURCE: Congressional Budget Office based on *Budget of the United States Government* (various years) and 1993 projections from the NASA Comptroller's Office.

NOTE: FY = fiscal year.

accounting for inflation. Currently, NASA's management is focused on adjusting its program to accommodate the total of $4 billion in unresolved reductions--the bottom line of the January exercise.

The past provides guidance as to how the agency will eventually resolve its current problem. In adjusting to lower budgets in future years, NASA and the Congress have:

- Canceled programs--for example, the Comet Rendezvous/Asteroid Flyby Mission and the Advanced Solid Rocket Motor for the space shuttle;
- Scaled back and diminished programs--notably, the space station, the Earth Observation System, and the space shuttle annual flight rate; and
- Delayed programs--for example, the advanced tracking and data relay satellite.

The agency also reduced its federal workforce--a continuing theme in the current period--to comply with an across-the-board reduction in federal employment ordered by the President.

Equally important, during 1993, NASA embarked on a number of efforts to improve its management and financial control with the objective of buying more program for less money. In a 1994 report, CBO reviewed a set of proposals initiated by NASA to improve the way it conducts business. Those proposals included making changes in management, procurement, and planning; placing greater reliance on the private sector and international partnerships; streamlining the agency's organization; and changing its organizational culture by employing the principles of total quality management.

It is still too soon to say whether those and other similar reforms will allow the agency to buy more for less. It is encouraging that improvement is evident in program cost and schedule estimates, implying general improvement in project control. Yet more detailed evaluation of specific NASA initiatives--for example, cost savings associated with applying the principles of total quality management to NASA's operation--have not been undertaken. Success in those enterprises, however, remains imperative in carrying out NASA's program within its current budget and in accommodating that program within even smaller budgets.

THE NEXT ROUND OF REDUCTIONS AND THE FUTURE

NASA has not specified how it will close the remaining gap of $4 billion in its 1996 budget, and CBO cannot be certain how the agency will eventually accomplish that feat. The changes necessary to get from the 1995 to the 1996 plan are instructive, however. The agency combined a search for gains in efficiency with cuts, deferrals, and limits in program activities in a continuing effort to close the gap between the great expectations of the early 1990s and current budget realities. NASA may do so again in resolving this year's problems. As noted in previous testimony and CBO's 1994 study, gains in efficiency may be difficult to realize and take several years to account for budgetary savings. Moreover, NASA is counting on as yet unrealized gains in efficiency--for example, in operating the space shuttle--to live within its original budget plan for 1996. The tougher choices of downsizing the institution and the program now remain if NASA is to live within the budget proposed by the President.

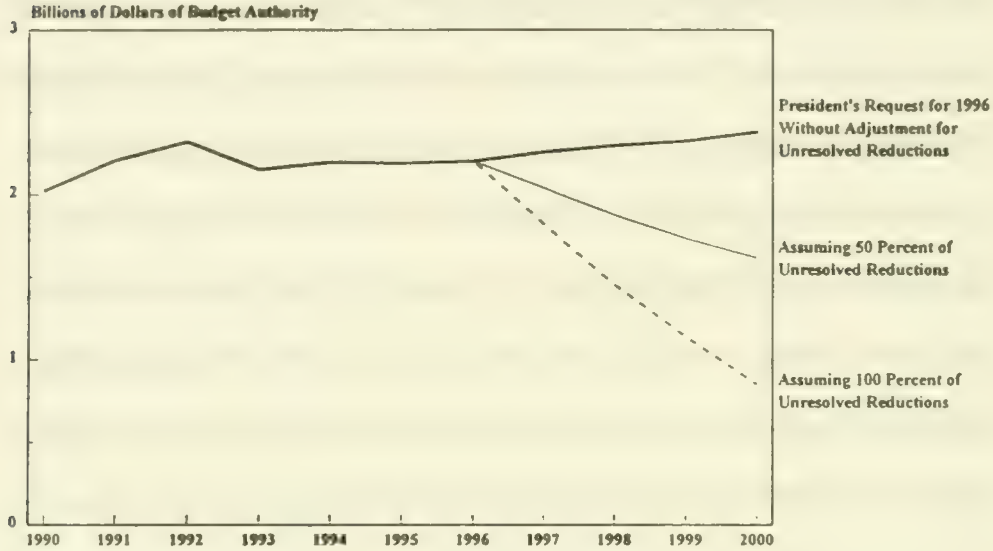
Downsizing the Institution

Some people suggest that NASA approach its problem in the same way that private firms have when forced to "downsize." The agency's current effort to adjust to lower budgets emphasizes reductions in personnel and the institution, so that the program can be saved. That approach is analogous to a private firm's effort to restructure by reducing the resources devoted to middle-management functions and eliminating redundant functions and facilities. Moreover, it is consistent with the type of changes NASA initiated in 1993.

Successfully adopting that approach to downsizing requires NASA to make larger-than-proportional reductions in overhead and management functions so that more valued program dollars can be spared additional cuts. To date, by the imperfect measures available, NASA has not made substantially greater than proportional reductions in its overhead. The research and program management (R&PM) category of NASA's budget, which was $2.2 billion in 1995, includes the funding necessary for salaries, benefits, travel requirements, and other support for the civilian workforce and the necessary funding for all of NASA's administrative functions that support research in NASA field centers. Program accounts certainly include additional overhead costs, but the R&PM category captures a large part of NASA's spending for overhead. For 1990 through 1995, the share of NASA's budget accounted for by R&PM spending moved down only slightly from 16.4 percent to 15.1 percent of the agency's budget authority. During that same period, the share of salaries and expenses--a component of R&PM--grew from 10.3 percent of the agency's budget to 11.4 percent.

Under the 1996 budget plan, before correcting for the unresolved reductions, research and program management spending would enjoy small increases each year from 1996 through 2000 (see Figure 2). The R&PM share of NASA's planned budget authority would increase to 18.1 percent, and the category for salaries and expenses would grow to 13.8 percent of the same total, if projected spending in those accounts was left unchanged in NASA's plan to fit its program into a smaller overall budget.

FIGURE 2. FUNDING FOR NASA'S RESEARCH AND PROGRAM MANAGEMENT UNDER ALTERNATIVE SCENARIOS TO COMPLY WITH THE PRESIDENT'S REQUEST FOR 1996 (By fiscal year)



SOURCE: Congressional Budget Office based on the *Budget of the United States Government* (various years); National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1996*, vols. 1 and 2; and unpublished information from NASA's Comptroller's Office.

NOTE: From fiscal year 1991 through fiscal year 1994, research operations support (ROS) funding was budgeted and managed by the NASA program offices with institutional responsibilities. In the fiscal year 1995 budget, ROS funding was consolidated in the appropriation for research and program management account/mission support.

Although NASA has not spelled out how it will close the $4 billion gap in its budget, larger-than-proportional reductions in overhead are consistent with themes sounded by the agency's management. For example, absorbing half of the $4 billion reduction in the R&PM accounts, over the 1997 through 2000 period, would result in a projected funding level of $1.6 billion in 2000, or 12.3 percent of the agency's projected budget. If the entire reduction was taken from overhead, the level of funding for R&PM would be $847 million in 2000--in other terms, about 39 percent of the 1995 level and about 6.4 percent of the agency's projected budget.

Under its current plan, NASA projects that its full-time-equivalent civil service workforce will fall from about 23,100 in 1995 to 20,900 in 2000. Reductions far below that level would be necessary if the overall R&PM budget was reduced. The reason is that the salary and expenses category of R&PM that pays for the civilian workforce accounts for 75 percent of total R&PM and is, after a point, more easily adjusted than other parts of the accounts that cover the fixed costs of keeping NASA's field centers open. In the time permitted to prepare this testimony, CBO has not been able to prepare an estimate of how much NASA's civilian workforce would have to be reduced to fit within lower R&PM budgets. Substantial reductions would probably be necessary, however.

The amount of benefits that would be lost by reducing R&PM to the levels just discussed is unknown. Eliminating redundancies and expertise in the government that can be purchased from private industry may result in some budgetary savings. One person's redundancies, however, are another person's means to provide fail-safe mechanisms and to ensure that a sufficient level of technical competence is spread throughout the agency to allow a healthy competition among ideas and approaches. Moreover, personnel cuts that reduce the government's ability to be a smart buyer may in the end cost more than they save.

Finally, some people question whether NASA could possibly maintain the scope of its current program with a federal workforce that might be only half of its current size. From this perspective, it might be preferable--and even imperative--to reduce the agency's scope of activities as well as downsizing its overhead.

Narrowing the Product Line

In its previous testimony, CBO examined a more radical approach to living with less. NASA could reduce its budget by narrowing the focus of its program and eliminating, rather than scaling back, parts of the agency's traditional agenda. Specifically, the agency could be directed to mothball its piloted spaceflight program or to shut down most of its unpiloted space science activities. That approach is also analogous to another widely used strategy in the private sector that seeks to restore profitable operation to a struggling concern by narrowing its scope of activities. The approach achieves cost savings by selling off lines of business and the facilities that go with them. Improved performance is realized by concentrating the remaining assets of the firm on fewer markets and objectives.

CBO's 1994 report developed three alternative programs that each focused on specific parts of NASA's current product line--namely, a program emphasizing human spaceflight with an annual budget of $14.3 billion, a program that emphasized space science and maintained piloted spaceflight for that purpose with an annual budget of $11 billion, and a program that emphasized space science and technology development and eliminated piloted spaceflight for an annual budget of $7 billion.

Since the release of the report, some people have questioned the costs associated with those options. For example, NASA has indicated that the savings from eliminating the space station program but maintaining the shuttle for limited use would only be about $1 billion annually rather than the $3 billion implied by the second option. A recent estimate approximating the third option that would eliminate both the space station and the space shuttle placed annual savings at around $5 billion (after covering smaller savings for one year when termination costs were paid). By that estimate, the agency's annual budget would be around $8 billion rather than the $7 billion included in CBO's third option.

CONCLUSION

Despite the differences in budget and savings estimates, CBO maintains that the options developed in its 1994 report generally remain workable. Narrowing the product line offers an advantage compared with across-the-board downsizing. It forces the Congress and the agency to decide what is NASA's best mission at a time when resources are constrained. Continued decreases in the resources available for the civilian space program will force NASA to face the prospects of closing major centers and making additional large cuts in its federal workforce beyond those that might be proposed to fill the gaps in the 1996 budget plan. A more narrowly defined mission will permit the agency to make better choices about what should be kept and what must be abandoned. Ultimately, such an approach may provide taxpayers with the highest return for their investment in the civilian space program.

Mr. SENSENBRENNER. Thank you very much, Mr. Moore. Next is Mr. Wolfgang Demisch of Bankers Trust in New York.

Mr. Demisch.

STATEMENT OF WOLFGANG DEMISCH, BANKERS TRUST, NEW YORK, NEW YORK.

Mr. DEMISCH. Thank you, Mr. Chairman. Restructuring is a costly experience, as at least in business and I suspect it is also so in government.

It is costly in time. You lose good people. You lose focus. And, obviously there is an up front expenditure required.

So, ever since Roman times, we've had steady warnings that restructuring is something that you do infrequently and that is very damaging to do repeatedly. NASA has been, as near as I can tell, subject to repeated restructurings over the past several years, as the budgets have eroded pretty steadily from the recommendations of the Augustine panel for growth to the real declines that Mr. Moore has pointed out.

I think that this is demoralizing and damaging in any organization. But, it's especially so in an R&D shop where there is no established support constituency because there is no established product.

Here, fear is maximized. And, all parts suffer, however, and especially given the repeated cuts.

I think we have the experience of Eastern Airlines in our sort of general industry where cutting off the dog's tail an inch at a time eventually led to the dog dying. It's not something that I think we should recommend.

And, I think we should keep that in mind as we address the subject of restructuring.

NASA is an organization which has a dual role. First, and perhaps least important, it is to be a cradle of innovation to serve the industry and our country. And, second, and probably more essential, at least in my view, is that it's supposed to be a source of inspiration for people, young people especially.

And, I think that any restructuring that is undertaken should preserve and enhance these objectives and that the restructuring effort should be judged on that basis, not so much on the basis of the financial impact. And, of course, we are talking money here.

And, as I understand it, we are talking about a five billion cut over five years on a roughly 14 billion dollar a year budget. That's seven percent.

It's an adjustment. It's not a restructuring. It's not a dramatic change. It's just another in a series of cuts.

And, I think that unless it is accompanied by some more specific congressional guidance, especially in terms of goals and priorities, against which the success of the effort is going to be measured it's not going to be anything other than something which slows the pace at which NASA delivers on such programs as it has.

Now, given the above, I think that Congress would helpfully view NASA in a broader context and start to set its priorities and hold the agency accountable. Given the reality of declining budgets, it would also be helpful to provide for reduced obligations to ensure that the tasks—that the priority tasks and innovation especially are not sacrificed in the process.

In this context, there would seem to be at least some recommendations. First of all, I think that NASA requires—or that the priority for being sacrificed should be some of the routine tasks that NASA performs which ideally should be out-sourced.

Two elements here jump to mind. First of all, NASA's involvement in the space transportation business makes NASA the lightening rod for any accidents that happen. I think it's inevitable that sooner or later we will lose another shuttle.

I think it's extremely dangerous to have the shuttle being represented as the national space program. And, I think it would be highly desirable if this were in some way, shape or form put out to a contractor. It would be much more satisfactory, I think, and much safer if an accident were at a contractor level rather than at a national level.

Secondly, I think that NASA's budget is increasingly being infringed by a wedge on ongoing support of existing programs—the Hubble space telescope, for instance; the various national observatories; the mission to planet earth coming up—which are going to require open-ended support at an increasing level to implement the science that they make possible. It's not clear to me that that's necessarily within the NASA—within the scope of the NASA budget, but NASA is paying for it.

Thirdly, I think that NASA requires, and Congress should mandate, some stretchy—and I use the word advisedly—objectives, some missions which really challenge the technology and the capabilities of the country. A very deep space flight, for instance, would be one of these, very lightweight aircraft structures would be another, high speed flight would be another, automatic flight would be yet another.

Any and all of these are multi-agency tasks which, I think, NASA could help coordinate and perform and which would benefit us all.

Thank you.

[No testimony submitted for the record.]

Mr. SENSENBRENNER. Thank you very much. Next is Mr. Rick Tumlinson, President of the Space Frontier Foundation in New York.

STATEMENT OF RICK N. TUMLINSON, PRESIDENT, SPACE FRONTIER FOUNDATION, NEW YORK, NEW YORK.

Mr. TUMLINSON. I would like to thank the Chairman for this opportunity. I would also like to thank the Chairman of the Full Committee as well for opening up the Committee room a couple of weeks ago for an informal session that was held by several organizations involved in space.

You are going to hear a lot of different speakers today of different sorts. You are going to hear people who are cheerleaders for the agency. You are going to hear people talking about the way things have been and working from that background.

And, you are going to hear some new ideas. I urge you to please pay attention to the new ideas.

I am not here to talk on a heavily detailed level about the state of our space program. I would rather not spend my time rearranging the deck chairs on what I consider the Titanic of that—that is our program but rather look at a way we can begin to launch, shall we say, thousands and thousands of new ships into the sea of space.

The country at this time is facing, I think, a period of some malaise. Some have attributed this to the national debt.

I think it runs deeper than that. I think for the first time in our history we have no frontier. And, we are a nation of pioneers.

We have no external enemy around which to organize our activities, our actions, our nation, nothing to bring us together. In a democracy, the tendency might be at that point to begin turning on ourselves. And, I think we are beginning to see some of those trends.

I think we are facing the beginning of our third century as a nation. And, it's time to take a look at the space program and see what that can contribute to the beginning of the next century.

The space program to date has been basically a program that has been modeled on, to be honest, nationalist, socialist Germany. It was appropriate, when needed, to fight the Cold War, to beat the Russians to the top of the hill and plant the flag on the moon.

It has ever since tried to repeat that behavior. Commissions have come. Commissions have gone.

Basically, they have recreated the litany of space shuttle, space station, moon base, Mars base, laid out by von Braun in the 50s. All of these commissions have failed, every one.

Why have they failed? They have failed because they are not in tune with the American people.

The space program, as currently organized, is not based on an American model. The model we believe the program should be based on is that of the American frontier.

And, so what I am about, what my organization is about is turning the space program on its head, to have the space agency, rather than performing stunts for the American people, spend its time and effort helping the American people get into space and do what they do best, which is create wealth, create freedom, create opportunities. The way we have to do that is to, throughout the agency and throughout the government, permeate all of those who are creating policy, making policy and carrying out policy with the belief that they are here to help the American people.

I think we are tired of watching CNN in the morning and hearing what music the astronauts have woken up to. I don't think that has anything to do with what we are about as a nation. And, that is the core of our problems.

I think we can change budgets. We can change internal priorities. But, we are not going to get there that way.

The space program we have today has never been oriented towards putting the American people themselves in space. Twenty-five years after Lewis and Clark went west, the wagons were rolling. Twenty-five years after the Wright brothers, you could buy a ticket and fly on a plane.

Twenty-five years after we landed on the moon, we watched old astronauts on t.v. last year. This is how you create generation X, putting the greatest moment in human history in the past and spending your time dwelling on trying to recreate some pale ghost of that.

We have to take the greatest moments in history and put them into the future. And, we have to do that in such a way that the largest number of the American people can participate in meaningful ways in creating that future.

The way we can do that is to adopt a few principles. We call them the space frontier principles. You can word them or apply them how you will.

The first principle, Number One, is: Space is a place. It is not a program.

Number Two. In free enterprise democracies, opportunities are exploited by individuals or groups in the form of companies and private institutions.

Number Three. Frontiers are not opened by governments for the people but by the people enabled by their governments.

Number Four. Without extremely low cost, reliable and regular access to space, there can be no frontier at all.

Now, these are all great words. And, we know that the agency is very, very good at adopting rhetoric. They have done it repeatedly and often. They have done it to suit whatever times they are in.

I would—could I ask for a couple seconds more? I would ask that we look at these—at the way we are approaching space in the future and we test these things, we test these things that the agency provides that the government is going to be doing, and we use what we call the frontier enabling test.

If I could read the one paragraph of the test to you, sir. Thank you.

Our definition of a frontier enabling technology or policy is one which has as its effect the acceleration of the creation of low cost access to the space frontier for private citizens and companies, enables or accelerates our use of space resources and/or accelerates the rate at which wealth can be generated in space. In other words, is the project or policy going to provide a return on the national investment if we define return to be the economically, sustainable human habitation of space?

If we can apply that test and stick with it and avoid the rhetoric, I think we can transform what it means to be an American by transforming our space program and putting it in the hands of Americans.

Thank you.

[The prepared statement of Mr. Tumlinson follows.]

Manifesto for the Frontier

A Call for a New American Space Agenda

Testimony
to the
Space and Aeronautics Subcommittee
of the
U. S. House of Representatives
March 16, 1995

SPACE
FRONTIER
FOUNDATION

by Rick N. Tumlinson - President

Who we are

The Space Frontier Foundation is an all volunteer organization of American citizens dedicated to the propositions that:

(a) It is human destiny to open Space Frontier,
(b) this must be achieved within 50-100 years or humanity may well begin to slide into a new dark age,
(c) America, as a Frontier nation has a special responsibility and actual need to open this frontier,
(d) the current US. space program is not doing so,
(e) and it must be replaced with one that will.

Due to our adherence to this set of beliefs many consider the Foundation to be one of the most radical space groups in the nation. Others consider us to be one of the most common sense and consistent space groups. (Usually outside of the Beltway.)

Our views are published regularly by many of America's leading newspapers and magazines, and Foundation spokespeople appear often on radio and television across the nation.

As part of the promise to the visionary physicist we are dedicated to keeping the pivotal book "The High Frontier" by Gerard K. O'Neill in print as long as we exist.

In 1989 we delivered over 50,000 signatures calling for a return to the Moon to then President George Bush. Some language from that campaign was included in his 1989 Apollo Anniversary speech.

In 1990, while most of the space community was still talking of NLS and Shuttle 2 designs, we created the term Cheap Access to Space (CATS) and began the fight for radical reductions in launch costs as a key to the frontier.

In 1991 we took on NASA over the space station in such arenas as the New York Times, at a time when the project was going out of control. (Subsequently there was a major shake up of the program.)

In 1992 we issued a public call for the resignation of a NASA manager we believed was inappropriately trying to sabotage the fledging DC-X effort. This was an action almost unheard of in the space community.

We are largely internet based and our alerts and calls to action have repeatedly played pivotal roles in keeping the SSTO concept alive.

We Need A New American Dream

The greatest nation that has ever existed is about to face the dawn of a new millennium, and it is nervous. Americans are uncertain of their future. Although we are into our third century as a nation, a constant litany of doubt echoes across the land. American taxpayers want to know where their nation is going now that the Cold War is over. The people want a new vision of tomorrow, a vision which includes them in a real way, a vision toward which they can strive. People seek an understandable vision of what the next millennium will offer their children that is better than today. So far there is no such a vision out there.

In fact, if you ask most people to close their eyes and describe in terms of well known movies what tomorrow will look like, they often describe a world that resembles either the cold gray global cityscapes of the film "Blade Runner" or the post apocalyptic barrens of "Mad Max," or worse....they see nothing.
The screen of their future is blank.

Meanwhile, global leaders speak of a future in which everyone makes due with less in a more strictly regulated world. According to what these doomsayers tell us, our future is to be inevitably characterized by a slowly declining standard of life, and our children's' destiny is to be nothing more than caretakers for an already depleted world. Recently, discussions of the last election centered on Americans' uncertainty of what tomorrow will bring, how they are seeking a new focus, and crying out for leaders to point the way into the future. Desperately, pundits of all stripes have tried to describe this feeling, each observation based on their own biases and agenda, but all agreeing as to its existence.

It is our premise that this uncertainty is because we are nearing the end of a major phase of human existence and our growth as a nation. For the first time in the history of the planet there is nowhere left to go for those who wish to leave the old. or create the new....or, to put it more exactly...there is nowhere left to go which does not harm this planet, or is not the property of someone else.

We are a nation of pioneers with no new frontier. Nor do we have a clear external enemy around which to organize ourselves. It is said history repeats itself. But this is the first time in history these challenges have arisen on a global scale and no one seems to recognize the full implications.

Various leaders have from time to time tried to call for new organizing principles and activities for the nation. (Usually this occurs near elections.) Each attempting to find something to fill that blank image of tomorrow. Most have strongly partisan suggestions, involving moral or social crusades, and they all retread old ground.

No one is offering real new possibilities, but rather is rearranging various parts of our culture and its activities. None of these ideas seem sufficient to fire the imaginations of any large sector of our nation, or exciting enough to inspire our people as a whole in even a general way.

Former President John F. Kennedy came very close to bringing us all together when he pointed our nation at the Moon. During Apollo, many thought that our space program would eventually provide this bold new human future. It has not done so, and it cannot by its very nature.

Why is it that what should have been well on its way to being the central defining activity of this nation, has instead drifted into the category of socially expendable government spending? What happened? If one looks at the simple and obvious realities of its derivation and self defined goals since the "Moon Race," the reasons our space "program" is in its current moribund state become obvious.....

The US must recognize the philosophical dissonance between what the nation needs to do in space and what we are actually doing. Then we can begin to change our misdirected space program into a new national space agenda that is ever more inclusive, exciting and profitable to the nation. With this change we who understand the possibility of the space frontier can then give America a new picture of its future. A hopeful future, an exciting future, one that motivates our entire society. A future of endlessly expanding new choices.......

Just as Kennedy spoke of when starting Apollo:
"We go to create new choices...new freedoms..."
What did he mean...these are not things which can be discovered by astronauts, robots or even NASA managers. What did he mean? Who did he mean?
We may never know, as he was taken from us while Apollo was still being organized

We believe he meant all Americans.

We believe that we all have the "right stuff." We believe that given cheap access and encouragement, Americans of all types will forge from the seeming emptiness of space the greatest renaissance humanity has ever experienced.

Apollo and the Fall of America

Here we are more than a quarter century after the first and last moon landings and Americans still can't enter the frontier they paid to have explored. Yet it has been over 25 years since the first two government employees walked on the Moon. A lot should have happened in that time. But it hasn't.

25 years after Lewis & Clark; wagons were rolling west to Oregon, and clipper ships were plying the coasts of California with thousands of new pioneers...25 years after the Wright Brothers; people could buy a commercial ticket and fly in a plane...But 25 years after landing on the Moon we sat around watching old astronauts reminisce on TV about the good old days.

Over and over again we heard that Apollo was the greatest moment in human history....but this is an event which occurred before a significant portion of our population was even born. It appears we have placed our greatness in the past and plan no future wonders. This is one part of how a culture creates a generation "X." In fact one can be sure the fall of Rome was characterized by references to the events and edifices of the past, beginning with the phrase "Remember when....." This way lies the end of American civilization.

It is time to reverse this decay of spirit. Time to turn the depressing and oxymoronic ideology of sustainable development (read - "sustainable decline") on its head and create a new era of ever expanding hope and reduced pressures on our mother world. To do so we must put the greatest moments in history back into the future, and we must offer the chance to participate in their realization to as many Americans as we can - as soon as we can.

This can only be done through the creation of a free, open and expanding human frontier in space. A frontier built by all types of individuals and groups, working in all types of ways, to do all types of new things there. Powered by the glorious chaos of the democratic free enterprise system, we can break out of humanity's self imposed cage and create a bold future of opportunity.

We Have the Wrong Space Program

So where are we on achieving the goal of an open frontier in space?
We are not even trying. The status quo in our space activities is not working to this end. It cannot work. Why? The reason is simple and very basic:

It is impossible for a government owned and operated program to produce an open frontier in space.

It is not a matter of scale, or of budgets, or even of time, but of fundamental purpose and design; it isn't set up to do that.

Let's face it, our space program is based on a W.W.II German National Socialist model. What we in the Foundation call the Von Braun Paradigm, it is a system of thought and action that seemed appropriate for an important campaign in the Cold War. Its purpose was to help win that war by demonstrating US technological leadership and to act as the peaceful manifestation of our development of an advanced nuclear capability. The centralized, state run project orientation of the space program's founders fit well into our need for a quasi-military, goal oriented effort to beat the Russians and plant the Stars and Stripes at the top of the Lunar hill. It succeeded in this accomplishment, but has failed the ever since.

Since the end of the race to the Moon the NASA has tried to repeat this model, suggesting several variations on the Von Braun plan for a single national owned and operated space station, space fleet and government bases and outposts on the Moon and Mars. Commission after commission was created, diligently tried to steer the agency's course back to these original goals, and then faded away, to be replaced by yet another. Often made up of the same inside players, these groups have always made their suggestions from well within the old paradigm of the state performing for the people. And they have also always failed.

Thus, decades after W.W.II, and years after the Cold War ended, our national space agency is still basing its human operations more on our relationship with Russia than on its relationship with its own people. We must face reality. All of the high sounding speeches by NASA managers, all the pretty pictures and speeches by orbiting astronauts, all of the exciting animation and color pictures, all simply act to disguise a simple fact:

The purpose of the US space program is not and has never been to open space as a frontier for everyone.

The Space Frontier Principles

To date the national space program has often been elitist and exclusive. Rigidly adhered to, it has never included the people for whom it was allegedly created, and ignored at its own peril several essential truths.

The United States is a confederation of free peoples bound together by the belief that the people have primacy over the state, and that individuals should have the power to create new wealth unimpeded by that state. The settlement of our own western frontier was a result of the application (often by default) of these core concepts. Extended and applied to space, they add up to what Foundationers call the Space Frontier Principles.

The members of the Foundation believe that unless these ideas underlie our future space plans they are doomed to failure.

- **Space is a Place, not a Program**
- **In free enterprise democracies opportunities are exploited by individuals or groups in the form of companies and private institutions.**
- **Frontiers are not opened by governments for the people - but by the people - supported by their government.**
- **Without extremely low cost, reliable and regular access to space there can be no frontier.**

The Frontier Enabling Test

For Foundationers, space is the next great human frontier. A frontier such as the so called "New Worlds" of the Americas represented for the last 500 hundred years. A frontier we have to take from no one. A frontier to which we can bring the gift of life. A frontier for all humanity. A frontier we do not believe is being opened.

If we are truly committed to change we need a criteria by which to judge what we will and will not do to effectively advance our cause. Thus, the Foundation has created a relatively simple litmus test for projects and/or initiatives on which we may choose to take a position. We call this "The Frontier Enabling Test," and it can be applied to both government and commercial systems, technologies or policies:

The Frontier Enabling Test

Our definition of a "frontier enabling" technology or policy is one which has as its effect the acceleration of the creation of low cost access to the space frontier for private citizens and companies, enables or accelerates our use of space resources, and/or accelerates the rate at which wealth can be generated in space.

In other words, is the project or policy going to provide a return on the national investment, if we define "return" to be the economically sustainable human habitation of space?

This vision of an open frontier in space and this radically different role for the national government in space add up to what we in the Space Frontier Foundation call the **New American Space Agenda.**

The New American Space Agenda

Under the New American Space Agenda the national goal will be the creation of diverse in-space infrastructure & capability. The government's role changes dramatically, from performer to enabler.

NASA will become a long lead research partner, a maintainer of law and safety, a promoter of vision, an international arbiter and sometime even a partner in ventures deemed as good investments by the taxpayers.

This new cultural model for humans in space is not the Cold War, or Von Braun paradigms, but the entrepreneurial and spiritual energy of the American Frontier, as symbolized by the opening of North America and the old west by our pioneering ancestors.

- The nation will begin the active and energetic exploration and study of the solar system because it is humanity's extended home, precisely why President Thomas Jefferson sent Lewis & Clark across the continent, because he assumed it would all eventually be called "home."
- Humanity will engage in the full use of in-space resources, energy and the space environment itself, to create new goods and services for use in space and for export to Earth.
- The space frontier will be filled with the broadest possible range of beneficial ventures and activities, including industry, commerce, science, culture and tourism.
- The stated national goal will be that this is to lead to settlements, not just more missions, bases or simple outposts.

The New American Space Agenda will lead to a frontier which is growing exponentially and endlessly.....

The Role of Government on the Frontier

What will the governments' role be in this New American Space Agenda? First of all what it won't do is operate a monolithic, project based, national space program:

- Instead, the government will create framework for the safe expansion of civilization into space.

- Therefore the governments' approach will be to enable others to do things in space rather than "do"ing space for them.

- The White House must use the power of the bully pulpit to declare not another destination, but that space is now a frontier of opportunity for people & enterprises. This position cannot simply be left to mere words. It is a position which must be reflected by all of its employees and spokespeople in both words and deeds.

- The government will use its massive purchasing power to create and catalyze viable markets.

- The government will fund multiple parallel technology development and demonstration programs in cooperation with private sector.

- The government will act as regulator by creating a positive and consistent business environment.

- The US. government will work in the international arena as it does in other areas of world trade to assure free and fair markets, and level playing fields for innovative American companies - but not protection for failing ones.

- The government will use innovative support mechanisms such as prizes to leverage and encourage innovations and breakthroughs in our opening of space.

- Finally, the government will fund scientists to buy science and data, rather than taking them along as passengers on what are really engineering projects in need of rationales.

Example I : Cheap Access to Space

The primary goal for the nation in this decade must be achieving cheap access to space. Because if you can't get there regularly and cheaply to develop, test and manufacture your product you can't make a profit. If there is no profit, there will be no frontier.

How do we do reduce costs on Earth? The key is free and competitive markets. The national government should turn its demand for services now provided in-house into a first level market for space transportation companies. Although not enough to support the type of large scale transportation infrastructure we need for the frontier, the government is our first identifiable large scale user.

- NASA should announce the shuttle will be phased out as soon as new commercial fleets are ready to bid for payloads. The schedule for this hand off should be moved up in time to encourage the type of low cost innovation exemplified by the successful DC-X program, rather than the project accretion that seems to be the norm with NASA.

- Space policy makers should end any talk about a single new national vehicle. The US government must never again own and operate a national fleet of vehicles for civilian purposes.

- Instead, the government will build with industry X vehicles like SSTO X-33

- Congress should insist on and fund a fly off of prototypes. Since amortizing development is one of the major driving factors in launch costs, this would lead to several completed prototypes at a minimal cost to potential users.

- We must create a streamlined and non adversarial launch regulation, licensing and insurance regimen modeled on the way we deal with aircraft or high risk sports.

  (For example, responding to a paralyzing glut of ski related lawsuits, the state of Colorado implemented a new liability law which protects ski slope operators and equipment owners from law suits. This single action saved skiing in Colorado and resulted in the growth of one of the world's premiere winter sports industries.)

- We must pass legislation in support of or even offer cash prizes for RLV's to leverage innovation.

There is at least one group of space advocates who are trying to assemble the funds for a prize similar to that won by Charles Lindbergh's historic trans - Atlantic flight. This prize, known as the "X-Prize" was the idea of Foundation member Dr. Peter Diamandis (Co-Founder of the International Space University). It will be awarded to the first privately funded team to fly 6 adults on a sub-orbital flight of approximately 100 kilometers in altitude and then repeat the flight several days later. The key frontier enabling aspects of this idea are (a) The number of passengers required to win is designed to create vehicles which can then be used for commercial transportation purposes and (b) By repeating the flight only 7 days later the teams will demonstrate commercial style turnaround.

To date, several wealthy individuals have shown very strong interest in funding (and thus naming) the prize. Unfortunately, liability issues are keeping this idea from fruition. These laws must be changed..

Example II - The State Depts. Space Station

Clearly in the Foundation we're not fans of NASA space station Alpha as currently conceived. It simply does not pass the enabling test. We believe it would have been much better to simply buy elements of Mir on a commercial basis. Several years ago we called for this idea in the LA Times (August, 1992) .

We also hold the belief that any government space station bureaucracy operating under the current paradigm (and this has been shown repeatedly to be true) simply will not allow the existence of any private space facility which might threaten by example its rather generous budget.

We accept the station as a political reality. Thus, given the possibility it might someday be built, our goal as an organization has become transforming Alpha from a bureaucratic grain of sand into a frontier enabling pearl.

The key issue then becomes: Can we make Alpha enabling in terms of opening the space frontier?

The answer is yes we can. By making it the heart of a new industrial park and the seed of a new town in space. The states' role than becomes much like the role played by the government in the old west.......buying goods and services

- At the end of Phase One we must require that all cargo and crew transfers to and from the US elements of the station be commercially bid by American private vendors.

  The potential size of the launch services market to and from the space station complex for its first few years will not be enough to support a serious transportation industry. However, it can act as a driver for NASA supported R&D projects aimed at dramatic cost reductions such as the X-33 RLV effort. Also, in its position at the heart of the first community in space it can be the official "peg" in space to which the LEO transportation lifeline can be attached.

- At the end of Phase One we must require that all physical expansion of US elements of the station be commercially bid by American private vendors (and preferably operate detached from the main station.)

  There are at least three credible ideas for expansion of US capabilities that are frontier enabling all by themselves. When combined with the station's onboard capabilities and its existence as the core of our space outpost we can begin leveraging our habitable volume and begin the development of our town.

NASA's function on Station Alpha would be to support these activities and others we cannot yet foresee, thus private initiatives would move from being a threat to funding to become the justification for the station's existence. From projects like former astronaut Joe Allen's now dead Industrial Space Facility, to those firms wishing to create huge shirtsleeve volumes using recycled Space Shuttle external tanks, to proposals by the tried and true Space Hab organization to create space for science and research, a new impetus would be given. All would act as support for the others, for example, their joined needs would expand the transportation market, creating a virtual transport nexus, and drive down costs for all.

- At the end of Phase One we must require that all expansion of power on the station will be commercially bid by American private vendors. Preferably provided by an off site source.

One of the most exciting possible benefits to Earth that we find in space is clean energy in the form of sunlight. In fact the space station will draw its power from sunlight converted by solar cells into electricity. There have been dozens of conferences, papers and studies on the idea of capturing that "space power" and sending it to the Earth's surface where it could eventually feed much the world's electrical needs. The possible industry this would create would be enormous, and would compete with much more polluting forms of energy such as nuclear fusion. The last serious studies of this idea were made over 20 years ago and shot down the concept based on the extremely high launch costs at the time they were made. As we begin to achieve cheap access to space would it not be wise to begin encouraging the development of this potential source of endless energy?

At a minimum, a solar electrical plant in the Earth's neighborhood could become our first orbital utility, providing beamed power to all sorts of facilities and operations. This would mean that project builders would not have to build in expensive onboard main power systems and simply buy their energy from the new space grid.

Finally, there are many serious proposals for the development of low cost exploration probes which can be made much smaller by eliminating heavy on board power supplies and replacing them with power beamed from a fixed central location in the form of microwaves and lasers.

Example III - Near Earth Space

The area we call Near Earth is comprised of the Earth, Moon, nearby asteroids and comet resources. This area is unique in all the Solar System, since the costs of accessing it are far lower than other areas, and much time has been spent exploring its potential. We believe that NASA's Lewis and Clark's have done their job here in the neighborhood of Earth. Now it is time for the rest of the nation to take over. Near Earth should be handed over to universities and private firms to explore and develop for human use.

- To encourage this, our government should end its practice of undertaking its own missions in this area and help bootstrap low cost commercial and academic research by offering to buy its data from low cost providers.

  NASA science managers should be freed to purchase or support university based explorations with limited or single objectives as independent projects. In other words, a scientist needing a specific new data set on the geology of a certain area of the Moon should not have to wait for a multi-capable mission to be formed over the course of a decade or so, but should be able to put out a request for data and buy it by the unit from any available US source. There are several possible near Earth missions in need of relatively small amounts of money in exchange for a vast scientific return that are commercially viable yet are currently excluded from receiving government funds, due to the agency's need to be in charge at all times.

- The government should fund observatories and scientific research stations through universities and scientific institutions, with requirements that all infrastructure and support be bid for by US firms.

  There are still many large scale science projects which demand a strong and ongoing infrastructure. One exciting idea is the construction of a new Lunar farside observatory, made up of dozens of small telescopes that scientists say could combine their power to see objects as small as continents on planets circling other suns. In this case the NASA might well help form a team of co-operating universities and observatories. This team could then contract out the construction and operation of this project to companies which would specialize in economic Lunar surface operations.

- No more government employees should be sent to the Moon for artificial reasons of prestige or loosely disguised science. Instead, we must let the market decide when the time is right for humans again. (Keeping in mind that human habitation is our eventual goal.) Interestingly, robots will almost always be our first explorers when the bottom line is at stake, even when the desired final result is settlement. At last we can finally end the arcane and outdated robots vs. humans debate.

We must never again allow the mistakes of Apollo to be repeated. No more one shot Missions to the Moon, Mars or anywhere else, no more dead ends. No more flags and footprints.

Next time we stay *and* we make it pay.

The question of Mars

As currently envisioned by NASA, we do not see human Mars missions as frontier enabling. In fact, they fall under the category of stunt. However, the new approach to opening the Martian frontier being put forward by Foundation Advisor Robert Zubrin, under the title of "Mars Direct," might meet our criteria if and when the nation were willing to create a trust fund or other method of funding to pay for a multi billion dollar "Mars Prize."

The concept is based on creating an Earth - Mars transportation infrastructure and the maintenance of a permanent colony on the planet's surface which utilizes a significant amount of in-situ resources. As Mars holds such mystique for humans and is the most Earth like of all the planets, this might well someday become a viable idea.

It must be understood that this proposal does require a substantial national investment and may well have to wait for the national debt problem to be addressed, but the Foundation believes in democracy, and if the taxpayers can be persuaded and the goal remains the first permanent human settlements on the Red Planet, we support the concept.

Conclusion - A New American Frontier

If the nation chooses to adopt this New American Space Agenda we can transform America and the world's economic, social and spiritual future.

- Space firms new and old will have more work than they can possibly imagine now. As access increases demand will increase. The Catch 22 of space commercialization will be broken. Through the development of cheap access to space, firms can finally test, develop and produce new products in space economically. As more is produced in space costs will drop. As costs drop more profits will be made, as more profits are made more activities will occur and we will be off into a new future.

- The nation will redefine itself as it becomes focused on the new frontier. America will have a new national context that is powerful and endless. Imagine how we will see ourselves in 50 years if we really throw open doors to this enormous new frontier.

- We will be able to reverse the trend of humanity essentially attacking the living biosphere of Earth as its means of survival. We will be able to begin lowering the pressure on our precious mother world. Instead, and for the first time ever in our history, we shall take life to places where no life has existed before.

- There will be no question of where we as humans are going...our place in the big picture, or what we must do next. We will only have to look up at a thousand new stars scattered across the night sky to find the answer.

And the world will follow.
Because we are a nation of pioneers,
It is our frontier, and we all have the right stuff
It is high time **we the people** got a shot at proving it.

Mr. SENSENBRENNER. Thank you, Mr. Tumlinson. And, finally Mr. May from The American Legion.

STATEMENT OF GERALD M. MAY, ASSISTANT DIRECTOR, NATIONAL LEGISLATIVE COMMISSION, THE AMERICAN LEGION.

Mr. MAY. Thank you for having The American Legion here today, Mr. Chairman.

There are several reasons for us to be here. Chief among them is that the Legion has supported NASA and space endeavors and space education for many years, since the late 1950s.

Second, even though The Legion may be better known for its advocacy of a strong national security program and veterans health and welfare, the Legion believes that programs characterized as competitors of military or veterans issues can and must coexist.

Finally, The American Legion represents a worldwide membership of 3.1 million. We adopt resolutions on an annual basis that we believe are representative of the point of view of a lot of Americans.

On the issue of space and NASA and space education, The Legion's national legislative mandate is very specific—while change and progress are good for government, so is consistent direction and steadfast support to American objectives. The American Legion's role in aeronautics and space has been that of consistently projecting the ideals of The Legion that are mirrored in the ideals of NASA and the national space program.

We are dedicated to youth education programs for aeronautics and space and have been through affiliation with the Civil Air Patrol, aviation education programs and Aerospace Industries Association. Over the years, we have provided books and pamphlets, sponsored site visits and workshops and donated a great deal of money in support of young people and their schools.

Prime examples of The American Legion's interest are embodied in the programs conducted by Legion members in California and South Dakota.

In California, The American Legion's Aerospace Commission has worked for many years with state school systems, teachers and the Civil Air Patrol and NASA in conducting aerospace workshops for youth and their teachers to instill an interest in science and engineering career paths. Each year, the Department of California of The American Legion funds and cosponsors a myriad of events in concert with NASA, schools and universities.

Post 496 in Long Beach and Post 564 in Mission City have taken over American Legion cosponsorship of an aviation summer school located at the Western Aerospace Museum in Oakland. This four-week program attracts young people between the ages of nine and 14 and teaches them about the history and the national goals and accomplishments of aerospace programs.

With the help of The American Legion, NASA's Ames Research Center conducts an annual one-week workshop for teachers at Moffett Field. The program is called "Space Down to Earth."

It teaches aeronautics, astronautics, space science and computer fundamentals and is taught by Ames scientists and engineers on a volunteer basis. The American Legion provides scholarships to selected teachers who attend this in order to defray their personal costs.

The American Legion's Department of South Dakota, like each state's American Legion Department, conducts their annual Boy's Nation program. This activity educates and instructs the high school age attendees on the functions and purposes of government and the legislative process.

A crucial part of the South Dakota program is to hear first hand a personification of government accomplishments at their best. NASA astronauts have led and facilitated these discussions which have proved to be the most memorable and useful inputs to this annual program.

In view of the reorientation of science, national security, geopolitical and economic priorities, affirmation of new and lasting American objectives are required for all the manned and unmanned space programs. As the steward of the nation's civil space program, The American Legion believes NASA should be cost effective, managerially efficient and dedicated to focus on the uses and exploitation of space activities.

We know they do these things. But, we also know they sometimes overlook tasks in their near proximity vision and fail to eliminate those that are of low value and high risk.

We know that NASA is striving to succeed in an unforgiving environment, both in Washington and in space. The rules of downsizing, program cuts and narrowing of scope have to apply to NASA as it does to the DOD and the VA and others. But, we say let NASA recommend where to change.

Today's agreements with foreign nations for joint cooperation in space are essential if any nation or a group of nations are to succeed in exploration of space. Even though political stability for some of our partners may be unpredictable at this time, we expect the U.S. space program and NASA to grow in knowledge and experience through these liaisons.

Just as we have lifted the embargo against Vietnam and invested in North Korea to facilitate political and economic imperatives, we should seek and sign agreements for international investment in U.S. space engineering, production and technology and establish special working liaisons and agreements with other space-faring nations.

The American Legion believes the specific goals and objectives of the U.S. space program, based on adoption of a permanent national space policy which allows clear and definable progress in security, science and education, is critical. But, the policy has to be accompanied by a strategy much like that used in the Department of Defense and Department of State.

To be useful and unquestionable, this policy has to be consistent and based on predictable funding levels.

In this day and age of the shrinking but much in demand American dollar, the U.S. cannot afford to go it alone in space. If the NASA space program cannot interest other governmental agencies in providing sufficient resources, it should be allowed to have activities subsidized by block grants that should come from private companies or corporations or colleges and universities and even foreign nations.

Just as the Postal Service should be allowed to sell advertising space on its stamps and turn the profits back into the Service, and just as the VA should keep third party revenue to put back into veterans health care, NASA should be able to sell education programs, serve as consultants, provide a wide variety of services and do analyses for a profit for institutions, companies and countries.

Congress should continue to provide the appropriate funds for the NASA space program within the resources that are available. But, if insufficient funds are provided to meet programmatic goals, either the goal must be altered or creative funding initiative must be found.

The nation, as a whole, has always managed to maintain its sense of programmatic balance and values.

Mr. SENSENBRENNER. Mr. May, your time has expired.

Mr. MAY. I'm sorry, sir. I get carried away. I am so enthused about the space program and The American Legion's involvement in it.

Anyway, we hope that the Committee sees it our way as well.

[The prepared statement of Mr. May follows.]

STATEMENT

by

Gerald M. May, Assistant Director
National Legislative Commission
The American Legion

before the

Subcommittee on Space and Aeronautics
Committee on Science
United States House of Representatives

on

Support for the National Space Program

MARCH 16, 1995

STATEMENT OF
GERALD M. MAY, ASSISTANT DIRECTOR
NATIONAL LEGISLATIVE COMMISSION
THE AMERICAN LEGION
SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
MARCH 16, 1995

Mr. Chairman, members of the Committee, The American Legion sincerely appreciates this opportunity to testify before you in support of a strong and dynamic national space program.

There are many reasons for us to be here today. Chief among them is that The American Legion has supported NASA, space endeavors and space education for American's youth since the late 50's. We believe we are second to none when it comes to supporting all challenges that make America first in all things.

Second, even though The American Legion may be better known for its advocacy of a strong national security and veterans health and welfare, the Legion believes programs characterized as competitors of military or veterans issues can and must co-exist.

Finally, The American Legion represents a world wide membership of 3.1 million. We adopt resolutions on an annual basis that we believe are representative of America's point of view on a variety of issues.

On the issue of space, NASA and space education, The American Legion's national legislative mandate is very specific -- while change is good for government, so is consistent direction and steadfast, unwavering support to American objectives.

The American Legion's resolution on support for the National Space Program goes on to say that the space program has kept the nation on the leading edge of the technological frontier, has created jobs and has improved diagnosis and treatment of health care ailments experienced by veterans and all Americans. It has fostered new scholastic interest in space science, provided insight into the evolution and state of the earth, its environment and its solar system, and has provided visions and objectives for the future for business, industry academia and the nation's youth.

The U.S. space program has been on programmatic and emotional highs and lows since its inception. The American Legion's role in aeronautics and space has been that of consistently projecting the ideals of the Legion that are mirrored in the ideals of NASA and the national space program. Our advocacy of the nation's space program is tailored to our convictions on the needs of America. The country and its youth need a vibrant, and productive national space program.

We are dedicated to youth education programs for aeronautics and space and have been since 1959 through affiliation with the Civil Air Patrol, and the National Aviation Education Program, which has since evolved to other purposes, and with the Aerospace Industries Association since 1966. Over the years we have provided books, pamphlets, sponsored site visits ar workshops, and donated monetary support to young people and their school and have recognized the accomplishments of space pioneers such as Major Robert White in 1962; Jim Young and Bob Crippin in 1981, and John Glenn in 1993. We have asked for an accelerated space program through the years in order to maintain the nation's technological edge in science and visionary thinking.

Prime examples of The American Legion's interest are embodied in the programs conducted by Legion members in California and South Dakota.

In California The American Legion's Aerospace Commission has worked for many years with state school systems, teachers, the Civil Air Patrol and NASA in conducting aerospace workshops for youth and their teachers to instill an interest in science and engineering career paths. Each year the Department of California of The American Legion provides funds and co-sponsors a myriad of events in concert with NASA, schools, universities the Air Force and communities.

Post 496 in Long Beach and Post 564 in Mission City have taken over American Legion co-sponsorship of an aviation summer school for young people at the Western Aerospace Museum in Oakland. With the leadership of Mr. Guy Marschner of Weed, California and in his capacity as Chairman of the Aerospace Commission with The American Legion, and the invaluable help of NASA, government, industry and San Jose State University in that area, this seventeen-year-old program can continue.

This program attracts young people between the ages of 9 and 14 and teaches them about the history, the national goals and accomplishments of the nation's aerospace programs. This four week annual program instills lasting interest and involvement in air and space systems developments in the hope that the young attendees will be inspired to pursue a career in aerospace.

With the help of The American Legion, NASA's Ames Research Center conducts an annual one week workshop for teachers at Moffett Field. The program is called "Space Down To Earth". It teaches aeronautics, space science and computer fundamentals and is taught by Ames scientists and engineers on a volunteer basis. Without the dedicated support of NASA professionals like Dr. Garth Hull, Mr. Thomas B. Clausen and Dr. H.Gene Little this vital workshop would not exist. It is paid for by the attending teachers themselves. The American Legion provides scholarships to selected teachers in order to defray personal costs.

The American Legion's Department of South Dakota, like each state's American Legion Department, conducts their annual Boy's Nation program. This activity educates and instructs the high school age attendees on the functions and purposes of government, the legislative process and the procedures followed by state and nationally elected officials to govern and enact legislation. A crucial part of the South Dakota program is to hear first hand, a personification of government accomplishments at their best. NASA astronauts have led and facilitated these discussions whi have proved to be the most memorable and useful inputs to this annua program.

In this day and time quality role models are crucial to the establishment of lasting attitudes, values and beliefs for young people desirous of entering public service. Without NASA's help on this project we could not declare our South Dakota Boy's State program a complete and unqualified success each year.

The greatest service we believe we can perform in aerospace is to give support to youth education programs and defend research and development in advanced space systems so that at no time is there a possibility that other nations can achieve a technological breakthrough that would place the United States at an economic or national security disadvantage. We also believe our efforts can contribute in many small but important ways toward instilling and maintaining widespread public acceptance of, and interest in military and civil aerospace, and also emphasize the need for a dynamic space program.

On July 18, 1914, more than 80 years ago, Congress created the Aviation Section of the Signal Corps in the United States Army. It consisted of 60 officers and 260 enlisted men. Today's military and civilian astronauts, and NASA's scientists and engineers stand in tribute to the wisdom of that legislative act. It is a miracle that in the span of time since 1914, flight by man has advanced from "crates" of fabric and wire to spacecraft and satellites -- from flight speeds of 45 miles per hour to escape velocities of 25,000 miles per hour. Veterans have been involved from the beginning.

The importance of aerospace knowledge, ability and systems has been learned the hard way. We found this true when the Legion was founded in 1919 after World War I, and find it true today as we grapple with complex problems like disease, crime, Bosnia, health care and manned space flight.

NASA and the space program have been criticized for many years for failures experienced or lack of progress in directions space policy observers thought the country should go. From the first major space program catastrophe involving three Apollo astronauts in a capsule fire in 1967, to the Challenger accident, to the Hubble Space telescope anomaly, to the most recent problems with faulty thrusters, glitches in black boxes, to less than warm space suits and gloves, we find NASA and the space program striving to achieve success, persisting and persevering in an unforgiving environment -- in Washington and in space.

The American Legion recognizes the production and use of space systems technology, the spin-off research and the products derived from it are vital components of the nation's economy. And, our national economic security is becoming more intertwined with our national defense security as time goes on. Space programs have not only kept the United States on the leading edge of the technological frontier, but also have created jobs, fostered new scholastic interest in space science, have provided insight into the evolution of the earth and its solar system, and a vision into the future. What is most important is that it challenges the minds of those who would be future astronauts, scientists and engineers.

In view of the reorientation of science, national security, geopolitical and economic priorities, affirmation of new and lasting American objectives are required for the manned and unmanned national security, civil and commercial space programs. As the steward of the nation's spac program, The American Legion believes NASA should be cost effective, managerially efficient organization dedicated primarily to focus on the uses and exploitation of space activities. They should keep in their near proximity vision, rapid elimination of those programs that are of low value and high risk. The rules of downsizing, program curtailment or cut, and narrowing of scope should apply to NASA as it does to the DoD, the VA, and others. But let NASA recommend where to change.

The nation is long overdue for a space lift program using a new generation of launch systems, propulsion engines, metals and fuels for affordable launch into space. NASA should be heard on this issue.

Today's agreements with foreign nations for joint cooperation in space is essential if any nation or group of nations are to succeed in exploration of space. The United States has enjoyed many successful pacts with other nations for trade and mutual defense for years. Even though political stability for some of our partners may be unpredictable at this time, we expect the U.S. space program and NASA to grow in knowledge and experience through these liaisons. If agreements should become outmoded, they should be replaced with substitute participants. Just as we have lifted the embargo against Vietnam for political and economic reasons, we should seek and sign agreements for international investment in U.S. space engineering, production and technology, and establish special working liaisons and agreements with other space-faring nations. But, we should be selective and seek those who share U.S. goals, ideals and simila policies. NASA counsel should be sought on this.

The Congress and the President can take the lead in establishing and adopting a rock-solid policy on the use of the nation's space programs, business ventures in space and joint space colony and planetary exploration tasks. If a "Made in Space" label could make a difference in U.S. national defense and economic security, we are for it. I am confident that NASA and many public organizations share this view.

The American Legion believes the specific goals and objectives of the U.S. space program, based on adoption of a permanent national space policy which allows clear, definable progress in security, science and exploration, is critical. But, the policy must embody a strategy much like the national security and foreign relations strategy statements prepared by the Departments of Defense and State. It should address economic objectives, academic achievements, scientific goals, foreign agreement intentions, financial limitations, youth incentives and other specifically expected payoffs. To be useful and unquestionable, this policy and strategy must be consistent and based on predictable funding levels.

In this day and age of the shrinking, but much in demand American dollar, the U.S. cannot afford to go it alone in space. If the NASA space program cannot interest other governmental agencies in providing sufficient resources, it should be allowed to have activities subsidized by block grants from private companies or corporations, colleges and universiti and foreign nations.

Just as the Postal Service should be allowed to sell advertising space on its stamps and turn the profits back into the Service, and just as the VA should keep third party payer revenue to put back into veterans health care, NASA should be able to sell education programs, serve as consultants, provide a wide variety of services and do analyses for a profit for institutions, companies and countries.

The point is, Congress should continue to appropriate funds for the space program within the resources that are available. But if insufficient funds are provided to meet programmatic goals, either the goal must be altered or assured, alternative funding sources must be found.

As the agency to which this nation's scholastic incentive and pioneering spirit is entrusted, NASA must be able to learn from its tasks and agreements, adopt constructive and creative initiatives and move ahead.

Mr. Chairman, The American Legion believes that beyond technology, the nation's greatest resource is the will and determination of an informed and involved citizenry. Few of us can be expected to claim expertise in the discipline of space science, engineering or space exploration. But, all of us have an instinct for survival. The nation as a whole has always managed to maintain its sense of balance and values. Over the years The American Legion has made significant contributions to the public understanding and support of national space objectives. Without support to the U.S. space program, NASA and the vanishing aerospace industry that supports both civil and military aerospace needs, we fear the U.S. could lose its technological leadership.

The American Legion hopes the committee agrees.

Mr. SENSENBRENNER. I would like to thank the members of the panel. I would like to ask a couple of questions, if I could, specifically of Mr. Moore and Mr. Demisch.

First, Mr. Moore, your figures that the administrative overhead of NASA has only gone down from 16 percent in 1990 to 15 percent in 1994 are truly shocking to this member of the Committee. We have heard from Mr. Goldin again and again on how NASA is becoming better and cheaper and slimmed down. And, he comes up with all these plans.

And, it looks like the bottom line really has not improved in a significant manner in terms of redirecting the dollars that Congress appropriates away from the NASA bureaucracy and into programs that can bring a result back to the American taxpayer and allow those of us who support NASA in Congress to justify to increasingly skeptical taxpayers why this investment is worthwhile.

Having made that observation, let me say that this afternoon, I am going down for my annual visit to the Johnson Space Flight Center. What do you think I ought to tell them, given the figures that you've come up with?

Mr. MOORE. Well, let me say, first, that in our longer written statement, we do note that simply using the research and program management account as a measure of overhead is imperfect. I'm sure that Mr. Goldin's response on that score might be that NASA has eliminated overhead that is carried in program accounts. And, certainly overhead is carried in those accounts.

I stand on our testimony that the options to consider are perhaps beyond the level of what you might ask of Johnson Space Flight Center and are options that the Congress might want to consider in terms of narrowing the agency's product line. Far be it from me to suggest that I know better how to run a space agency than the individuals down there at Johnson.

Mr. SENSENBRENNER. Perhaps we might nominate you some time in the future for that.

[Laughter.]

Mr. SENSENBRENNER. Mr. Demisch, the privatization option of NASA operations, particularly operations of the shuttle, are one of the considerations that we hear NASA is actively pursuing. And, we will find that out when the initial recommendations become public on the 17th of May.

If NASA decides to go this route and the Congress agrees with NASA, how quick do you think this transition can take place?

Mr. DEMISCH. I think it could be done within a year provided—and this is a major caveat—there is an agreement on the scope of responsibility. There currently isn't a thing like a certificate of operations for spacecraft as there is for aircraft.

There is no sort of regulatory standard. And, I think that a contractor would want to be very heavily indemnified if he was operating something which was subject to continuous government scrutiny and where he didn't have the opportunity to say, "It meets the spec. I'm going from here."

In other words, it's hard to privatize something unless you know exactly where the privatization starts and where it ends. The problem right now is that the shuttle is an ongoing work in progress every time and there is no limit to the amount of government involvement necessarily.

And, to privatize it, I think there would have to be that. I think a year is by no means an unreasonable time frame for that.

But, of course, I'm not a lawyer. So, I may be speaking out of turn.

Mr. SENSENBRENNER. Particularly with respect to the civil service laws.

Mr. DEMISCH. Well, that's—you raise a very touchy point. And, I think you are absolutely correct that—the shuttle, as it stands right now, I think employs some 30 odd thousand people. And, I think a fair number of these have civil service protection.

And, I think the process by which you can disengage that is going to be laborious at best.

Mr. SENSENBRENNER. Okay. Thank you very much.

The gentleman from Minnesota, Mr. Luther, do you have any questions?

Mr. LUTHER. No, I don't.

Mr. SENSENBRENNER. Okay. Thank you very much. I would like to thank the members of the first panel for coming to appear and giving some very valuable testimony so early in the morning.

Absent members of the Committee may wish to direct questions of you. I will set a deadline of a week for the members of the Committee to propose their questions.

We will forward them on to you. And, we would appreciate if you do receive some questions to have your written responses back within a week or 10 days after receipt so that we can button up the hearing record and get it printed and distributed.

So, thank you again for coming. Your testimony has been very useful.

The second panel this morning will be on the subject of the space station and the space shuttle. The witnesses are: Mr. Richard Kohrs, the Director for the Center for International Aerospace Cooperation in Arlington, Virginia; Mr. Norm Parmet, Chairman of the Aerospace Safety Advisory Panel of NASA; Professor Hans Mark of the Department of Aerospace Engineering of the University of Texas in Austin; Dr. Max Faget, Space Industries International in Washington, D.C.; and, Ms. Lori Garver, Executive Director of the National Space Society in Washington.

Mr. Kohrs, why don't you lead off for five minutes?

STATEMENT OF RICHARD H. KOHRS, DIRECTOR, CENTER FOR INTERNATIONAL AEROSPACE COOPERATION, ARLINGTON, VA.

Mr. KOHRS. Thank you, Mr. Chairman. Unlike the last panel, my testimony today is very limited.

I was asked to address the space shuttle safety program in my view and also to look at my views of the space shuttle safety program as a result of this ongoing Functional Work Force Review that NASA conducted over the last four months.

My background is 31 years with NASA, 10 on the Apollo, 16 on shuttle and five on space station. I was in the shuttle program when it started in 1973, helped develop the specs, the requirements and the safety process. I was also there after the Challenger accident when we recovered from the safety of flight.

For the last four months, I've been doing part-time consulting with Brian O'Connor, the Space Shuttle Director, on this Functional Work Force Review. And, I had an opportunity—even though I was gone from the shuttle program for five years, I had the opportunity to see how things were progressing at Kennedy and Marshall and the Johnson Space Center and the Stennis Space Center.

My overall view on shuttle safety is what I found is that the processes that we put in place in—that Admiral Truly set up in March of 1986—on return to flight safety still exists today. I think the rigor that was put into the program then and the manpower that was put into the program to assure shuttle safety is—the majority of that is still there.

I think it's measured in the 43 successful flights that we've just completed. I think the flight that is up today is the 43rd flight since the Challenger accident.

And, I feel confident that it's being maintained. While this was going on—and you are probably aware in this Committee that the shuttle program has essentially reduced its operating budget by one billion dollars over the last three years—1992, 1993 and 1994. My view of that is that they've done that by still maintaining safety and maintaining the safety processes.

In late 1994, NASA created these 12 functional work force review teams that were independent teams to go look at shuttle from a bottom-up standpoint. I participated in those reviews.

I think those 12 or 15 independent teams were dedicated people, not program people. The first thing they did is they validated that what had been done between 1992 and 1994 created no safety issues.

The other thing they did, they came up and looked at the 30 thousand work force that's in shuttle today, roughly 27 thousand contractors and a little over three thousand civil servants. They broke their—these teams, when you put them altogether, in my opinion, come into two categories.

They come in the first category that says there is easy things you can do, things that are duplication, overlap and things that the program agrees that are easy to do. Those are already being implemented. That's probably two thousand out of a five thousand potential work force reduction that came out of these reviews.

The second category are things that are a lot harder to do and things that go back and change the processes that were set up to assure shuttle safety. My opinion, in looking at it—and I'm not there everyday—is that a lot of those can be done.

But, they ought to be done very slowly. My estimate is you cannot unilaterally say, "Go change the way the process was set up."

But, you can sit down within the program, within the program management, and say, "I want to change this," and all agree that that's the right thing to do. And, I believe you can slowly reduce the work force reduction.

My view is that it will take one to two years, one to two years to accomplish that.

My other recommendation is that this activity that was conducted was done by dedicated people not in the program. They have completed their mission. They have identified areas where you can make additional cuts.

It has now got to be put back in the program. And, it is.

And, I think you will see the shuttle budget being reduced and these operations areas over the next two years that will approach what these teams recommended.

That's the end of my statement. And, I will be glad to answer any questions.

[The prepared statement of Mr. Kohrs follows.]

Testimony of

Richard H. Kohrs
Director,
ANSER's Center for International
Aerospace Cooperation

March 16, 1995

before

Subcommittee on Space and Aeronautics
U.S. Congress

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Richard H. Kohrs
Director,
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Aerospace Cooperation
Testimony to Congress
March 16, 1995

INTRODUCTORY REMARKS

Mr. Chairman and members of the Subcommittee:

I am pleased to appear before the subcommittee to respond to your request for information on my views of the Space Shuttle as related to the safety process and in particular to the NASA Functional Workforce Review.

PERSONAL AND PROFESSIONAL BACKGROUND

My name is Dick Kohrs. I'm a native of St. Charles, Missouri and grew up in the St. Louis area. I received my degree in Mechanical Engineering from Washington University in St. Louis.

I have been involved with aircraft and space programs since 1953. I was employed by McDonnell Aircraft during my college career and for seven years after graduation until 1963. I spent the next thirty-one years at NASA. Twenty six at the Johnson Space Center and five at NASA Headquarters. At Johnson Space Center I spent 10 years on the Apollo program and 16 years on the Space Shuttle program from 1973 to 1989. When I left the Shuttle program, I was the Deputy Director. From 1989 to my retirement in 1993, I was Director of the Space Station Freedom program.

I have been employed at Analytic Services Inc. (ANSER) for the last six months. ANSER was formed in 1958 as a public service research institute to support U. S. aviation and space programs. ANSER provides objective, unbiased analysis, responsiveness, and insight in support of the public interest of the United States. On behalf of the U. S. Government, ANSER has studied Russian Space Capabilities and evaluated ways to strengthen the American space program by incorporating technologies and capabilities from the former Soviet Union. ANSER established a Moscow office in 1992 and currently staffs the office with 2 American engineers and four Russian nationals. In November 1994, ANSER created the Center for International Aerospace Cooperation (CIAC) to advance the development and operation of aviation and space programs that require international cooperation. I became the first Director of CIAC in November 1994.

I started in the Shuttle program near the beginning, was involved with the development of the specifications, design, interfaces, and the control procedures and mechanisms that established the safety process for the program.

I was involved in the Apollo 204 Fire Recovery, all of the Apollo flights including Apollo 13 and thirty flights of the Shuttle including the Challenger disaster and the recovery and return to safe flight.

The experiences I have had in program management and in developing and managing my portion of the return to flight activity after the Challenger disaster provide the foundation for my views on the Shuttle Safety process today.

Also, over the past 4 months, I have served as a part time consultant to the Space Shuttle Director. During this time, I have participated in the reviews of the twelve Shuttle Functional Workforce Review teams with the Shuttle Director. This activity provided me with a first hand view of the program, the areas of proposed workforce reduction, and an opportunity to interact directly with the people that conducted the review as well as the people and managers being reviewed.

OVERALL ASSESSMENT OF SHUTTLE SAFETY PROCESS

The Shuttle program has been 100% successful since the return to flight with 43 highly successful missions. The requirements that were established for the return-to-flight for STS-26, established a strong safety awareness, and the majority of the safety processes are still in place today.

From my insight into the current workforce review and the projected reductions, I believe Shuttle safety will be maintained. The program must go slow and be deliberate when making any change that may effect safety. My belief is that the current management will look at the workforce requirements and will systematically make the proper decisions to either keep the requirements in place or modify them accordingly.

BACKGROUND

After the Challenger disaster, there was a strong emphasis to return-to-flight safely. The NASA Associate Administrator for Space Flight established a strategy for return-to-flight two months after the Challenger disaster. The response to the above strategy put in place many of the safety policies that exist today. The return-to-flight strategy was endorsed by the Rogers Commission and by the U.S. Congress.

Besides assuring the redesign of the Solid Rocket Motor (RSRM) the strategy for return-to-flight also required a complete review and recertification of design requirements; re-review and reapproval of all hardware failure modes effect analysis and hazards; review and approval of all critical items that are criticality 1 (no - redundancy) and criticality 1R (at least one level of redundancy); review of the operational maintenance requirements (OMRSD's); and review of operational maintenance instructions (OMI's). The OMI's are the instructions to the Launch Processing Project on how to install, modify, check, and test flight hardware.

A key point in addition to the review and approval of the OMI's was that the work performed by the launch processing project in implementing the OMI's would include the design centers concurrence which includes the hardware manufactures concurrence. This requirement plus the requirement that the Certificate of Flight Readiness (COFR) be endorsed by the program, projects, and contractors contributed to a substantial increase to the Shuttle workforce prior to return-to-flight.

The Shuttle program started to systematically reduce its operations budget in 1992 and by 1994, had reduced the budget by approximately 1 billion dollars per year while still maintaining the flight safety standards and processes. The reductions came from savings associated with a reduced flight rate, efficiencies in management, flight operations, launch operations, and fewer program requirements changes.

In August of 1994, NASA established twelve independent Functional Workforce Review teams to review the Shuttle projects at four NASA centers (JSC, MSFC, KSC, and Stennis). These teams performed detailed reviews of the contractor and civil service workforce over a 4-month period and looked at staffing and tasks of approximately 27,000 Shuttle employees. In my participation with the twelve Function Workforce Review teams, I was impressed with the quality of the people on the teams and with their determination to understand the program structure and working relationships. The Functional Workforce Review teams did not identify any safety issues as a result of the 92 - 94 budget reduction.

WORKFORCE REVIEW

The results of this review have been summarized by the Shuttle Director to NASA management and to Congressional staff. I won't restate the results but I would like to present my views based on my participation.

My summary of the activity is that future workforce reductions fall into two categories.

The first category is work that can be eliminated or reduced due to changes in how business is conducted. In general, the program has agreed with these changes and many changes have already been included in the program planning to meet the FY 1995 budget. These changes do not effect flight safety.

The second category involves either changes to processes, contract structure, and/or program structure. The majority of these changes, in my opinion, can be implemented but they must be carefully reviewed by the program to determine any overall impact on flight safety. I estimate that this category of changes will take on the order of 1-2 years to implement.

CONCLUSIONS

My assessment of the Shuttle Safety Review Process as related to the Functional Workforce Review is that no actions have been taken that compromise Shuttle safety. There are proposals within the Shuttle Functional Workforce Review recommendations that if implemented without a thorough program review and program commitment could increase the risk.

Overall, any follow-on activity needs to remain within the Shuttle program organizational structure. The independent review teams made an outstanding contribution to identify areas that should be considered for workforce reduction. The program has the responsibility for implementation and for assuring flight safety.

Mr. SENSENBRENNER. Thank you, Mr. Kohrs. And, next up is Norm Parmet, Chairman of the Aerospace Safety Advisory Panel of NASA.

Mr. Parmet.

STATEMENT OF NORMAN R. PARMET, CHAIRMAN, AEROSPACE SAFETY ADVISORY PANEL, NASA, WASHINGTON, D.C.

Mr. PARMET. Thank you, Mr. Chairman. I am pleased to be here.

I thought that I might briefly describe what the Aerospace Safety Advisory Panel is, since there are a bunch of new members up on the podium here and since there has been a lot of confusion both inside and outside of NASA as to what we are. First of all, we are a congressionally-mandated panel which was created in 1967 when the Apollo had a command module fire.

The purpose of the panel was to provide an independent outside look at what NASA does and is doing and will be doing. And, that has been our basic purpose.

They are a nine-member panel. They are comprised of experts in the various fields of aviation and space. None of them are employees of NASA, although some have been—had their careers within NASA.

After the accident with the Challenger, the Rogers Commission did a thorough job of recommending great changes to NASA. One effect this produced was a large increase in the amount of work, inspection and detailed effort involved in producing a shuttle flight. Some of this was necessary, but not all of it was.

And, those of us who have looked at some of the processes down there saw redundancies and repeat inspections, et cetera. And, we are pleased to see that NASA, in particular, has been working very hard in getting rid of the unnecessary aspects of these inspections on such items as what they call structured surveillance, which means make the mechanic responsible for the work he does, the technician responsible for the work he does, and not the inspector. And, it reduced the amount of inspection where down the line the inspection can be done without eliminating—without creating any problems.

We are concerned, however, with this large number of reductions that appear to be coming along. We have not benefited like Dick Kohrs has from Brian O'Connor's study. And, once we receive it, we will be looking at it carefully to see where we agree and where we don't agree.

I certainly would agree with Dick Kohrs that there is room for reduction. But, how much of it can be done and done safely is our concern.

NASA has already had two years of cutbacks. They have not touched the technicians yet. But, I am fearful that they may be doing so here and in doing so may reduce the flexibility of what they do down at the Kennedy Space Center.

So, we need to assess what this large cut is going to mean. And, I think that if it's done, it has got to be done with safety first in mind and schedule second.

Reducing from eight to seven flights a year may give a little bit of leeway. But, basically if you bunch up flights—if you look at this schedule, you will see, for instance, there are two flights scheduled in June—with a reduced work force, you are not—NASA is not going to be able to cope with that.

And, if there are pressures from the outside, such as this schedule to put the space station up to meet with the Russians, to do other things like that, I think we are going to run into trouble. And, so I think there is a need not just for a reduction to occur, which probably can over a couple of years, but there is a need to reexamine every other program that NASA has to see what impact this reduction has on everything that they are doing.

So, I would say this. I come from an airline who has been subjected to many, many cuts over the years of my career. And, if they are done carefully and with some forethought and with understanding of what isn't going to happen after that, they can be done safely.

But, our stress is safety first, schedule second.

And, I would say this in conclusion. I think the shuttle program has gone about as well as it has during the past year. The space station program is proceeding.

There's problems in dealing with the Russians, since they have a totally different philosophy in life. And, they have been very successful in space, but their approach is different. They do a lot of testing, but they don't have much data.

So, it's hard to examine what they are doing and decide how it will fit with NASA's program. But, we are doing as much as we can from the outside looking in, an independent assessment, to make sure that we feel that NASA is doing a safe operation.

I thank you.

[The prepared statement of Mr. Parmet follows.]

STATEMENT OF

MR. NORMAN R. PARMET

CHAIRMAN, AEROSPACE SAFETY ADVISORY PANEL

before the

Subcommittee on Space and Aeronautics

Committee on Science

United States House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

I appreciate this opportunity to appear before you to discuss the Aerospace Safety Advisory Panel's position on the topic of today's hearing. The Aerospace Safety Advisory Panel (ASAP or "Panel") was established by Congress in the aftermath of the Apollo Command and Service Module fire which occurred at Kennedy Space Center in January 1967. Congress enacted legislation to establish the Panel as an independent senior advisory committee to NASA. The Panel is comprised of nine members, plus consultants as needed, all of whom are experts in various fields of aviation and space. Pursuant to carrying out its statutory duties, the Panel reviews, evaluates and advises NASA management on those program activities, system procedures, and management policies that contribute to risk and impact safety. Priority is given to those programs that involve the safety of human flight (both aeronautics and space). The work of the Panel is continuous throughout the year. We conduct upwards of 50 fact-finding sessions each year using small groups from the Panel to explore areas within their expertise. Historically the Panel has been given unlimited scope in looking into NASA's activities with an eye toward both ground/flight safety, as well as mission success. The Panel's findings, conclusions and recommendations culminate each year in the publication of its Annual Report. This year's report will be available to the members of appropriate House and Senate Committees and Subcommittees, NASA and contractor senior management, and the general public following our meeting with the NASA Administrator on March 23, 1995. The NASA Administrator, his senior staff and NASA contractors look upon the Panel as an independent means to assure that program strengths are maintained and weaknesses are quickly identified and resolved. In the past, Congress has stated that the Panel provides an independent set of eyes and ears to assure them of proper attention by NASA to critical program areas. The Panel's activities provide an opportunity for both the management and "hands-on" personnel to take another look at those areas for which they are responsible. Finally, the Panel does not supersede any of the safety, reliability and quality assurance organizations throughout NASA and its many contractors, nor does it interfere with their day-to-day activities. The Panel does provide independent objective assessments and advice to NASA/contractor management, with emphasis on safety, that is not obtainable in any other way.

The Challenger accident brought into sharp focus the risks involved in Human Space Flight and the importance of safety. The Rogers Commission made a significant number of recommendations following the accident, all of which were implemented by NASA. As a result, all procedures and inspections were revised and readapted to the new requirements, thus leading to the considerably larger work-force required to support a Shuttle mission. A sizable effort has recently been expended to reexamine all these procedures and workload increases. As part of this reexamination, Structured Surveillance was introduced at the Kennedy Space Center. The goal was to eliminate unnecessary work and inspections in non-critical areas by empowering the technician performing the work with the direct responsibility for quality of the work he or she performs. Inspections have been eliminated, reduced or combined, especially where another inspection occurs later in the work process. This has provided for greater efficiency, increased the pride of ownership among technicians and reduced manpower requirements. Safety is maintained by auditing of the process by quality assurance personnel. This procedure is now beginning to be utilized in other areas as the inspectors and technicians gain experience in its application. The gradual introduction of this process was carefully planned and implemented. Thus far there are no indications of any degradation in the quality of work. It should be noted that a process very similar to Structured Surveillance has been in effect in the air transport industry for over twenty years.

The Panel believes that NASA continues to exhibit an increased safety consciousness in all its activities. The Panel is particularly pleased that our recommendations concerning the enhancements and modifications to the Space Shuttle Main Engine are now being incorporated. We stress, however, that research programs involving human flight into space and within the atmosphere are inherently hazardous. It is imperative that NASA continue its quest for increased safety in its activities. Safety and independent oversight functions cannot be allowed to become "routine" or buried beneath other organizational units. It is vital that as NASA continues to expand its explorations into the unknown, it does so with continued dedication to risk reduction and risk management that does not hamper critical research and development ventures. Over the past year, NASA programs have made significant progress despite the pressures of smaller budgets, tight schedules and the loss of experienced personnel in critical positions. Nevertheless, the possible impact on safety as a result of the recent severe budget reductions and the departure of key personnel due to downsizing and buy-outs, particularly in critical programs such as Space Shuttle and International Space Station, continue to warrant the Panel's attention and concern.

The International Space Station program continues to show progress. The initial organization as presented to the Panel at the Johnson Space Center placed the independent safety assessment function under the program manager. However, an independent assessment function can only be truly independent if the director of that function is established on the same organizational level as the program manager. In this way, any dispute automatically elevates to the next higher level of management for resolution. After the Panel brought this to the attention of NASA management, the organizational structure was changed so that now the head of the independent safety assessment reports directly to the Associate Administrator for Safety and Mission Assurance, thus providing true independence for this critical function.

We also remain uncertain as to the ability of the Russians to fully deliver on their commitments to the International Space Station. The Russians have a high regard for safety and have very experienced, high level managers involved in the decision making process. The success of the Russian space program is not accidental. Their approach to safety, however, is different from that of NASA and relies heavily on testing rather than analysis. The issue is whether or not critical data and/or components will be available when needed.

Recent reorganization and reductions in the work-force have led to turmoil and uncertainty among the NASA and contractor personnel. The Panel is particularly concerned about the latest proposal for the Space Shuttle program to suffer even more cuts in personnel in the near future. It is impossible to assess the effect of such a reduction without knowing the details. However, it is undisputable that NASA in general and the Space Shuttle program in particular have undergone several severe reductions in available resources in the recent past. Without standing back and assessing the effects of these previous cutbacks, there is a real danger that further across-the-board reductions, without regard to where they are taken or how fast they are implemented, will lead to a less than desirable situation. As long as there is turmoil, it is impossible to clearly define at what point you cross over from safe to unsafe conditions . Certainly one has to be concerned that the program is once again targeted for such a large hit after having experienced significant reductions over the past two years. The Panel is concerned at the overall effect this uncertainty and turmoil is having on the personnel who process the Space Shuttle. As a result, we have small team of experts from the Panel at the Kennedy Space Center this week gathering information and assessing the situation. Of course, one immediate impact of reduction in resources has been the reduction in the number of Shuttle flights per year from eight to seven. However, with the importance of the joint U.S./Russian missions and the beginning of the Space Station assembly process, this does not necessarily relieve any pressure on the schedule. We continue to believe that NASA must maintain the philosophy of "Safety First, Schedule Second". If it does, and NASA approaches planned reductions with care and deliberation, executed from a known and well-established baseline, then I believe that a successful transition can be safely accomplished over the next five years. Of course, any reduction in the number of Space Shuttle flights will have effects on other programs such as the Space Station and scientific missions like the Astro 2 that is in orbit as we speak. Therefore, a full reexamination of these programs will also need to be made.

That concludes my prepared statement. I would be pleased to answer any questions or discuss any matters that may be of interest to the members of the Subcommittee.

Mr. SENSENBRENNER. Thank you, Mr. Parmet. Professor Mark from the University of Texas in Austin.

STATEMENT OF HANS MARK, PROFESSOR OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, THE UNIVERSITY OF TEXAS, AUSTIN, TEXAS.

Mr. MARK. Mr. Chairman and members of the Subcommittee, it's a pleasure and an honor for me to be here today to join this group.

I spent more than 12 years working in NASA, a little more than eight as Director of the NASA Ames Research Center and then almost four as Deputy Administrator of NASA from 1981 until 1984 which were, of course, the first years that we flew the space shuttle and we also developed the original plan for the space station at that time. I also served as Secretary of the Air Force and as Director of the National Reconnaissance Office which operates our intelligence satellites.

I say these things to point out that I've had some experience in the space business and how we do things.

On the question of managing the shuttle and what we should do with it in the future, the important principle is to separate NASA's development responsibility from the operational responsibility of running the shuttle. NASA is a first-class engineering development organization. It is not an airline or an operational organization. The shuttle should be run as an operational vehicle and not as a developmental enterprise.

When I left NASA in 1984, I actually left a set of recommendations which later appeared in the public prints. One of these recommendations was that we take the steps to move the shuttle out of NASA to contractor—more into a contractor mode and eventually perhaps do what we did with communication satellites back in the 1960s. The government set up a government-sponsored corporation called COMSAT to run those satellites. That was in 1962. And, then when these things became profitable in 1969, the government stepped out.

I would agree with Mr. Demisch that probably we are not talking about an operation that will ever really become profitable. But, there is no reason why one can't set up an organization like COMSAT to run the shuttle and perhaps also other launch vehicles that the United States fields; and, therefore, develop a mechanism for more rationally deciding what flies on which vehicle.

I recommended that in 1984. I did it again in 1988 in an article published in "Space Policy." In 1990, the Augustine Commission picked up the same recommendation.

And, it is my judgment that what Mr. Kohrs talked about in terms of the committees that are now looking at the operation of the shuttle, it is my judgment or my feeling that these committees will also come to the same conclusion that we should adopt a method of operating the shuttle that has to do with turning it over to a private contractor.

I would like to second what Mr. Parmet said about safety. Safety of flight is a primary consideration.

It is something that all of us who are involved in flying the shuttle, as I was for the first 14 flights, take very much to heart. I believe that the transfer of the operation of the shuttle to a contractor could be managed safely.

We actually started that process back in 1982 when we turned all of the processing of the vehicle—that is, the work necessary to mount the payload in the payload bay and then integrate it properly into the vehicle, so that the flight crew could handle the job, we actually turned that over to a single contractor. And, I remember the safety issues that came up at the time, whether such a transition could be made from the way we were doing things in the first few flights to the new model.

The shuttle processing contract is still in place now, some 13 years later. Also, it is working properly.

And, it is an illustration of the fact that these transitions can, in fact, be managed in the time period of one or two years that both Mr. Parmet and Mr. Kohrs talked about. So, I believe that the safety problem can be handled and the management can be properly set up to do that.

My recommendation, Mr. Chairman, today is that we get on with it. Thank you very much.

[The prepared statement of Mr. Mark follows.]

Testimony Delivered Before The Space Subcommittee of the Committee on Science, Space and Technology, U.S House of Representatives

Hans Mark

March 16, 1995

Mr. Chairman and members of the subcommittee. It is a pleasure and an honor for me to appear before you. My name is Hans Mark and I am a Professor of Aerospace Engineering and Engineering Mechanics in The University of Texas at Austin. From 1969 to 1977, I served as director of the NASA - Ames Research Center and from 1981 to 1984, I was the Deputy Administrator of NASA. During my service in NASA I was directly involved first in the development of the space shuttle and later in its operation. I am therefore quite familiar with all aspects of the space shuttle system and its management.

After the first flight of "Columbia" in April 1981, we began to look at a number of alternative ways of operating the space shuttle. The fundamental principle we adopted was to separate NASA's development work from the operation of the shuttle. We felt at the time that it was important to have a program office at NASA Headquarters that was devoted entirely to the operation of the shuttle. This office was established and it was headed by Jim Abrahamson during the first three years of its existence. Another step we took once the first few flights were successfully executed, was to seek ways to consolidate the operations at the Kennedy Space Center. The first thing we did was to streamline what is called the "processing" of the vehicle before each launch. This is essentially the job of mounting the payload in the payload bay and then to "integrate" the various elements of the payload so that the mission specialists and payload specialists assigned to the flight could do the complex experiments that would be performed during the flight. We debated the subject for some months and finally decided that all of the "processing" for shuttle flights should be turned over to a single qualified contractor. We developed a comprehensive RFP and sometime in 1983 we let the "Shuttle Processing Contract" to the Lockheed Corporation. This was the first step toward reducing operational costs and also to eliminating duplication and management overhead. The processing contract has now been reviewed several times since then and it has been very successful.

After the shuttle processing contract was implemented, we also began to look at other organizational steps that might be taken to improve the operation of the space shuttle. One suggestion was that the lead center responsibility for space shuttle operations be transferred from the Johnson Space Center to the Kennedy Space Center. This step was not taken at the time (1984) because it was judged that the space shuttle operation was not yet mature enough. I accepted that conclusion but I also continued to think about the manner in which shuttle operations should eventually be organized. When I left NASA on September 15, 1984, I put the following words about space shuttle operations in my daily diary:

"There would be many problems; perhaps the most important ones were actually internal to NASA itself. Although the organizations to implement the space station program were put in place, the relationships between these and the other elements of the NASA organization were not well defined.. The most important of these is the space shuttle program. We have succeeded in making the shuttle an engineering success, and we have demonstrated many of the operational capabilities inherent in the idea of a reusable spaceship. What we have not yet done is to demonstrate that the shuttle is an operational and an economic success. It is not yet clear that the customers of the shuttle have the necessary confidence in the system to use it the way it could be used. This is true both of the commercial customers and of the Air Force. It is also not clear whether the cost of operating the shuttle system is well understood as yet. There is a fine line between "improvement" for operational reasons and "improvement" to get a better system. At the present time, there is no clear way of distinguishing between these, and it may not be possible to make this distinction as long as the shuttle is operated by NASA.

The fact is that NASA is an engineering development organization -- and a first-class one. The talent required for engineering development is substantially different than what is needed for operations. It may be that at some time in the next few years, a new operational organization will be established to run the shuttle. My own feeling is that the best way to do this is to follow the model we established in the 1960's when the communications satellites were "spun off" from NASA. What I am advocating is that a government-sponsored corporation be established to operate the space shuttle. This corporation, in the beginning at least, would be controlled by the government in that the government would own the majority of the stock. However, private investors would be encouraged to put money into the corporation. This is, of course, exactly what was done when the Communications Satellite Corporation (COMSAT) was established in 1962 to operate communications satellites. The interests of the military in the shuttle system would be accommodated by appropriate representation on the board of directors of the corporation and perhaps by requiring that some of the senior operating officers of the corporation be serving military officers. The two launch sites for the shuttle at the Kennedy Space Center and at the Vandenberg Air Force Base would be turned over to the new corporation. The mission control function for shuttle flights that is currently performed at the Johnson Space Center would be moved to the Kennedy Space Center. Eventually, it is possible that other launch vehicles in the inventory, or launch vehicles that are yet to be developed, will also be operated by the proposed corporation."

This diary entry was later published in 1987 in a book called "The Space Station: A Personal Journey" (Hans Mark, Duke University Press, 1987.) By the time I left NASA, I had come to the conclusion that the best way to separate the operational and the developmental functions of NASA would be to establish the new organization to operate the space shuttle and possibly other space launch vehicles as well. I also felt that there might be a good opportunity to bringing in the commercial sector as well by using the COMSAT model to develop the new space launch vehicle organization.

In 1988, I published a paper titled "A Forward Looking Space Policy for the USA" (Hans Mark, "Space Policy", Vol. X, pp 19-23, February 1988) in which the idea of a quasi-commercial organization for operating the space shuttle and other launch vehicles was developed more extensively. A copy of this article is attached to this testimony.

In 1990, the "Advisory Committee on The Future of the U.S. Space Program" headed by Norman R. Augustine released a report in which the separation of the operational from the developmental activities in NASA was strongly recommended. The report also recommends (item F, on page 40) that:

"NASA should begin the deliberate process of planning for the transition of the space shuttle from development to a more nearly operational status at Kennedy Space Center with continuing technical support from other centers, and with appropriate certification of safety considerations at each step of the transfer process."

I take this recommendation of the Augustine Committee very seriously because four of the twelve members of committee had direct experience in space flight operations. Anyone who is knowledgeable in space flight operations and who has looked at the problem in detail from outside NASA has come to the same conclusion: Space Shuttle operations should be managed from The Kennedy Space Center and that an operational element should exist at NASA Headquarters solely to oversee space shuttle operations.

It is now 1995 and these recommendations have still not been implemented. The argument against making any changes in the space shuttle management has always been that "This is the wrong time to make the change since we have a critical operation X coming up and making changes would affect safety of flight. Let's wait until operation X is finished". You can substitute for "X" whatever happens to be the next critical flight. Making organizational changes of this kind is never easy and it is most often unpalatable to the people who are affected. There is never a "right" time for making a management change of this kind and there are always going to be some risks. However, it is my considered judgment these risks can easily be managed, in this case. It is my considered opinion that the next step in the management of the space shuttle is to start by establishing an operational entity at NASA Headquarters to oversee the enterprise, to designate The Kennedy Space Center as the lead center for shuttle operations and to do all of this with a view toward eventually establishing a quasi-private COMSAT - like organization to run the shuttle. These things must be done if the full potential capabilities of the space shuttle are to be realized.

Mr. Chairman and members of the subcommittee, the space shuttles have been flying for almost 14 years. The time has come for to get on with putting an appropriate organization in place to manage it properly.

Mr. SENSENBRENNER. Thank you very much. I believe that the budget the President has sent us is going to force us to get on with it.

Dr. Faget, Space Industries International in Washington.

STATEMENT OF MAXIME A. FAGET, FOUNDER, SPACE INDUSTRIES, INCORPORATED, WASHINGTON, D.C.

Mr. FAGET. [Oral testimony attached]. Thank you, sir. Mr. Chairman and members of the Subcommittee on Space and Aeronautics, I certainly appreciate the pleasure to share some of my thoughts with you this morning on both the shuttle and the space station.

And, maybe you know, I was with the shuttle program from its very inception. I stayed with it until after the second flight at which time I retired from the NASA.

As a consequence, I had left the NASA prior to the onset of the space station program. For that reason, I will talk mostly about the shuttle.

However, as you know, the shuttle and the space station are becoming eminently tied one to the other as we go into launch and operational phase of the space station. About the only observation I can make in regard to the space station is that it's quite clear that the recent activity (directed by Dan Goldin) associated with cleaning up the space station organization, both within the government and in the contractor structure has been a very good move in the right direction. And, we have every reason to believe that the space station program will be successfully completed.

Turning back to the shuttle, I would like to say that, in my opinion, the shuttle is one of the marvelous engineering achievements of the century. It is the first time that we used a completely reusable system for space operations. That system being the orbiter which is returned essentially in a condition where you could just fuel it up and fly it again. Unfortunately, we do not do that. But, I think that it would be possible.

As a first of the kind, it's not surprising that all of the goals that we set out for ourselves at the onset of the shuttle program were not met, particularly the cost of operations. I will get into that as I go along.

The space station will depend on the shuttle to launch it. And, I can't help but say that with the increase in the orbital altitude & inclination of the space station. The shuttle program has been placed into a very difficult situation, which I should like to get into.

NASA's goal with the space shuttle is still to reduce the cost of operations. At the same time they are doing this, they are trying to improve the performance. And, I've got to say that we are looking at what you might call "therein lies the rub." Performance, safety, cost of operations are each in conflict with one another. The Committee must understand this. If you are going to increase the performance, you are almost certain to compromise safety. And, you are almost certain to increase the cost of operations. If you try to increase safety and are successful at it, you are probably compromising both performance and cost and so forth.

I might mention here that there is nothing that will drive costs as much as trying to fly something of questionable safety. The very fact that we are looking at possible failures in the orbiter during flight results in a great deal of activity on the ground to make sure that these catastrophic failures cannot take place.

Presently, in our SR and QA organizations, which are all safety related organizations, we have, I believe, still way too many people. Now, am I saying that if you reduce the number of people you might improve the cost? Yes.

If you reduce the number of the people, what will you do to safety? You may, indeed, improve safety.

There is only one level of people—those that are actually doing hands- on analysis, or hands-on work on the shuttle—that really make it safe. The majority of the SR and QA people, in my opinion, provided the overviews and paper trails in order to document what is going on. This activity, although worthwhile as you might look at it, tend to distract the activity of those people who are actually working on the job trying to make the thing go.

And, I believe that the organization could be further cleaned up if the—the fact that we have numerous contractors, not one but numerous contractors, involved with launching the shuttle plus numerous subcontractors, something in excess of 20 contractors when you look at the whole thing, these contractors must also coordinate their activity, one with the other, because whatever one contractor does must be understood and clearly approved of by other contractors if there is some interface between activities.

So, consequently, if we could clean that up, streamline the organization, shrink the organizational contractors to perhaps just a few, all of these things would improve safety and at the same time reduce costs.

[The verbal statement of Maxime A. Faget follows.]

STATEMENT OF MAXIME A. FAGET, FOUNDER, SPACE INDUSTRIES, INCORPORATED, WASHINGTON, D.C.

Mr. FAGET. Thank you, sir. Mr. Chairman and members of the Subcommittee on Space and Aeronautics, I certainly appreciate the pleasure to share some of my thoughts with you this morning on both the shuttle and the space station.

And, maybe you know, I was with the shuttle program from its very inception. I stayed with it until after the second flight at which time I retired from NASA.

As a consequence, I had left the NASA prior to the onset of the space station program. For that reason, I will talk mostly about the shuttle.

However, as you know, the shuttle and the space station are becoming eminently tied one to the other as we go into the launch and operational phase of the space station. About the only observation I can make in regard to the space station is that it's quite clear that the recent activity, directed by Dan Goldin, associated with cleaning up the space station organization, both within the government and in the contractor structure, has been a very good move in the right direction And, we have every reason to believe that the space station program will be successfully completed

Turning back to the shuttle, I would like to say that, in my opinion, the shuttle is one of the marvelous engineering achievements of the century. It is the first time that we employed a completely reusable system for space operations; that system being the orbiter which is returned essentially in a condition where you could just fuel it up and fly it again. Unfortunately, we do not do that. But, I think that it would be possible.

As a first of the kind, it's not surprising that all of the goals that we set out for ourselves at the onset of the shuttle program were not met, particularly the cost of operations. I will get into that as I go along.

The space station will depend on the shuttle to launch it. And, I can't help but say that with the increase in the orbital altitude and inclination of the space station the shuttle program has been placed into a very difficult situation.

However, NASA's goal with the space shuttle is still to reduce the cost of operations. At the same time they are doing this, they are trying to improve the performance. And, I've got to say "therein lies the rub " Performance, safety, cost of operations are each in conflict with one another The Committee must understand this. If you are going to increase the performance, you are almost certain to compromise safety And, you are almost certain to increase the cost of operations If you try to increase safety and are successful at it, you are probably compromising both performance and cost and so forth

I might mention here that there is nothing that will drive costs as much as trying to fly something of questionable safety The very fact that we are looking at possible failures in the orbiter during flight results in a great deal of activity on the ground to make sure that these catastrophic failures cannot take place

Presently, in our SR&QA organization, which are all safety related organizations, we have, I believe, still way too many people Now, am I saying that if you reduce the number of people you might improve the cost? Yes!

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And, I also believe that the organization could be further cleaned up by recognizing that numerous contractors, not one but numerous contractors are involved with launching the shuttle Furthermore, numerous subcontractors, something in excess of 20 contractors and subcontractors are involved when you look at the whole thing These contractors must also coordinate their activity, one with the other, because whatever one contractor does must be understood and clearly approved of by others if there is some interface between their activities So, consequently, if we could clean that up, streamline the organization, shrink the organizational contractors to perhaps just a few, all of this would improve safety while at the same time reduce costs

(Statement of Maxime A. Faget follows.)

STATEMENT OF
DR. MAXIME A. FAGET
FOUNDER, SPACE INDUSTRIES, INC.
BEFORE THE
SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Mr. Chairman and Members of the Subcommittee on Space and Aeronautics:

I appreciate the opportunity to share with you some of my thoughts on the ongoing space station and shuttle programs at NASA. My discussion will be primarily related to the shuttle as I have been associated with that program since its inception. On the other hand, I retired from NASA prior to the beginning of the space station program. However, I believe that great improvements have been made in the space station program under the leadership of Dan Goldin. Both the contracting structure and NASA's management organization have been significantly simplified and improved during the last few years. Consequently, it is reasonable to believe that International Space Station Alpha ("ISSA") will be a successful program.

In my opinion, the space shuttle is one of the great achievements in aerospace history. Although it's not completely reusable, it clearly has demonstrated the feasibility of completely reusable vehicles. This is most important since truly low cost transportation to and from space will only be achievable if we reuse our transportation hardware. However, since the shuttle is the first vehicle of its kind it should not be surprising that some of the goals of the program, particularly low cost operation, were not met. During the next decade the shuttle's primary mission will be to launch and service the various elements of the space station. And as a matter of fact it is the capabilities inherent in the shuttle that really make the space station program feasible.

During the last few years NASA has managed to make significant progress in reducing the cost of shuttle operation. However, still further reduction in operation costs are achievable and should be vigorously pursued. This, of course, must be done without any additional compromise to safety. However, in looking at some of the missions that the shuttle must perform in launching various elements of ISSA it is clear that as presently configured, the shuttle is lacking in performance. Therein lies the rub. More performance, lower operation costs, continued safe and reliable operation -- these three goals are normally in conflict with one another, i.e. performance is usually achieved by increasing cost and/or compromising reliability, and so forth.

In reviewing the ongoing safety effort at NASA one cannot help wonder just how effective the excessively large number of people involved in safety are in reducing the hazards of the mission. I cannot help but wonder whether or not many of these people are mostly involved in coordinating the safety effort with one another rather than being in the position and having the talents to recognize and correct real problems. Furthermore, there are only so many failures of such a critical nature to cause a catastrophe. It is my belief that 95% of the catastrophic failures will occur during the launch phase of the flight (approximately the first 8 minutes). During this period the shuttle is flying through the atmosphere and is being propelled both by the solid rockets as well as its main propulsion system. I might also mention that it is during this period that the shuttle is most highly stressed and consequently some form of accident has the greatest probability. Regardless of the organization, ultimately we must rely on the experienced hands-on experts within the NASA and contractor organizations that really understand the various facets of rocket-propelled flight such as flight control, structural loads, rocket propulsion, etc. Overlaying the judgement of these people at present are numerous reviews, excessive paper trails, etc. which may only serve to distract these experts from concentrating on their task of preparing the shuttle for a safe mission.

When the shuttle was originally designed, one of the primary design objectives was to reduce operation costs. To this end it was planned to install sufficient redundancy in the many individual subsystems, where possible, so that it would be practical to proceed with the launch even with a failed component in one or more of the subsystems. This was done by providing a redundancy level of four rather than the normally acceptable three which had been used in previous manned space flight hardware. As a consequence, if a component were to fail prior to launch the desired redundancy level of three would have still existed. However, during the first few flights it was naturally desirable to have all the hardware operational since we were then dealing with an untried system. Unfortunately, this high level of precaution was never abandoned. After the Challenger accident with a new emphasis on safety demanded and implemented, a strengthened and more extensive safety organization was created and a policy of planned launches with a failed component never implemented. Consequently, designing in four levels of redundancy in order to reduce operation costs has completely backfired, and now instead of assuring that a shuttle with only three levels is faultlessly ready for flight, the extra effort must be made to assure that the added fourth level is equally ready. The fourth level of redundancy also increases the chance of a failed component showing up during the final countdown resulting in costly launch delays while trouble-shooting the problem and correcting it. I do not wish to recommend any reduction in safety. However, I believe that some acceptable compromise can be made in reducing the number of safety related personnel and in easing the launch criteria to accept some reduction in available redundancy. Obviously this must be done by careful scrutiny of the implications of such changes, remembering that clear identification of responsibility will more than compensate for reduction in redundant personnel.

Earlier I mentioned that the shuttle will be used to provide launch services for ISSA. With ISSA flying at much higher inclination that originally envisioned, the shuttle's performance will have to be upgraded in order to be able to deliver some of the heavier elements of ISSA. This extra cargo weight can only be achieved by reducing the weight of the shuttle components (external tank, the orbiter, or the solid rocket boosters) or by increasing the thrust of the space shuttle main engines (" SSME's"). Most of the weight decreases envisioned represent decreasing structural weight. Structural weight decrease is usually accompanied by higher stress which may compromise safety and cost money to implement. Furthermore, any increase in concern about safety will inevitably cost more money during operations as additional analysis and overview will most likely be required. NASA has been developing a modified version of the SSME's. This modified version should improve reliability by increasing the size of the nozzle throat. The large throat nozzles are designed to reduce temperatures, pressures and stresses in the SSME and thereby decrease the chance of catastrophic failure. However, the large throats can alternately be used to increase the thrust if the present level of turbine temperatures and stresses are maintained. This is the approach that NASA is now planning for the large throat SSME's. However, this would only provide about 1/3 of the needed additional performance.

The SSME is a very high performance engine. Without the extremely high specific impulse and thrust-to-weight provided by the SSME's the Shuttle would not have been feasible. However, this was done at a price. The SSME's were originally specified to be able to operate for 7.5 hours (27000 seconds) between overhauls. This was specified with the idea of keeping operations cost to a practical minimum. It also represented at that time an achievable goal for contemporary work-horse engines such as the F-1 used on the Saturn. Presently the SSME's are normally operated .56 hours between overhauls. This number should be compared to 3600 hours for a general aviation jet engine and 1600 for a piston engine. An Indianapolis race car engine is expected to last the 500 miles (a little less than 2 hours). There should be no doubt that the expected probability of catastrophic failure and time between needed overhauls are related. Serious problems with the SSME's have been successfully dealt with by an extensive program of thorough inspections and, as often needed, repairs after each mission. The technicians and engineers involved represent a high degree of dedication, skill and expertise. They, and most probably they alone, make the SSME's safe to operate.

There is no doubt that any future compromise in safety will only result in increased operational costs as additional attention to detail and analysis will be required in order to avoid a catastrophe. It is my firm belief that rather than trying to reduce the weight of structural components in the space shuttle and continuing to maintain the high stresses in the SSME, that flying the shuttle without a crew would achieve the requisite performance for those missions that require large weight components. If there were no crew aboard much installed equipment could be removed from the orbiter and the mission could be flown with lower expendable reserves. This includes maneuvering propellant, reactants for the fuel cells and food, water, and personal equipment for the crew. It is conservatively estimated that with one of the orbiters permanently reconfigured to fly unmanned that, at a minimum, 12,000 extra pounds of cargo could be carried. This would allow NASA to continue to improve both safety and operation costs for their manned flight program using presently configured shuttles with the modified, more reliable large throat SSME's.

Finally, I would like to make a few remarks as to the direction in which the country's launch vehicle program should evolve. With the successful development and operation of the shuttle, our country is in a marvelous position to develop completely reusable launch systems. We should continue to operate the space shuttle so that we can better understand how cost can be minimized with future reusable systems. It must be understood that a reusable system has the potential to not only save money by the avoiding the cost of manufacturing new hardware every flight, but also should save a great amount of money in pre-launch operations wherein the vehicle is made ready for the next flight. The latter is so because if the data obtained from the previous flight indicates little or no problem, very little should be needed to make the vehicle ready to fly again. This is exactly how we operate aircraft. Unfortunately, very little advantage of this situation is achieved in our present space flight operations. We must also learn to operate the shuttle unmanned. This will not only provide a useful unmanned launcher adjunct to the present capability but will also provide an improved insight into how an unmanned, fully reusable system can be operated. Our first fully reusable launch vehicle should be unmanned.

A fully reusable system will be most cost effective if the design is extremely conservative. This means that highly stressed components and structures are avoided. It is my belief that this can only be achieved using a two stage system. Two stages provides a great relief from the need for extremely high performance and will make a truly conservative design a possibility. The present effort that NASA has invested in developing the technology for a single stage to orbit should be continued. This is because most of that technology would be directly applicable to the second stage of the two stage system. However, I would recommend that NASA cease to identify the development of the single stage to orbit as a goal since such a goal, in my sincere belief, is contrary to achievement of the practical low cost launch vehicle system.

Mr. SENSENBRENNER. Okay. Thank you very much, Dr. Faget.

Ms. Garver from the National Space Society in Washington.

Mr. FAGET. I had more to say. I don't think I used my five minutes.

[Laughter.]

Mr. SENSENBRENNER. We had the timer on. You are at about eight.

Mr. FAGET. Oh, okay.

Mr. SENSENBRENNER. Sorry. Ms. Garver.

STATEMENT OF LORI GARVER, EXECUTIVE DIRECTOR, NATIONAL SPACE SOCIETY, WASHINGTON, D.C.

Ms. GARVER. Good morning. Thanks for having me here today.

The space shuttle and the space station encompass really the whole human space flight capabilities of this country. And, members of my organization feel strongly about their continued success.

I represent the public perspective of the grassroots, tens of thousand of members of our organization, who want to see real results from the space program, not just jobs and contracts. We believe the primary justification for the space station is that it will provide a place for learning more about living and working in space, not only for life sciences research but things like developing technologies, space operations and life support.

In a recent editorial in the "New York Times," they claim that the space station and the space shuttle were not worth much because we aren't going anywhere afterwards. Well, I might agree with them if I thought we weren't going anywhere afterwards.

In fact, we are. The space shuttle and the space station are just the first steps to human expansion beyond earth orbit.

I think NASA has been too shy about admitting, as has the aerospace industry, this fact. NASA and the aerospace industry have been wary about admitting the station is a first step, because they are afraid this vision would be too much for Congress to accept.

Well, the leadership of this Congress, I think they may find a change. We held a seminar in this room less than two weeks ago and yourself, Mr. Chairman, as well as the Chairman of the Science Committee, Mr. Walker, as well as Speaker Gingrich, all laid out their vision for space. And, I believe it's time for NASA and the industry to stop being shy about where we are going and that the space shuttle and space station are just first steps.

As an aside—I know it's outside the jurisdiction of this panel—NASA is doing something to focus on the long-term vision and that is through the discovery program. And, I would urge you to support the lunar prospector mission.

Another key point I make in my written remarks is that the space station should not be viewed as just another step in a governmental long-term space activity but as the opening wedge for large scale, non-government activity in space. It will serve this purpose well if we pursue the proper policies during this 104th Congress.

The redesign station is finally on its way to existence. Appropriately, what was borne out of the Cold War will now ring in the new millennium.

I think that given the global economic problems that we have, cooperating with Russia and the other countries is something we need to continue to do. And, I note that your Subcommittee has had a lot to do with protecting the program from getting involved in super power relations.

The recent attempts of Senator Bumpers, in particular, to derail the program I think need to be watched and that your Subcommittee can play an important role there.

And, I want to turn to the space shuttle. What about shuttle safety? I will say a few controversial things, I believe.

We are not a technical group. And, we can't tell you if it takes 20 thousand, two thousand or 20 people to launch the shuttle safely.

But, certainly 37 thousand people is an awful lot. And, it doesn't take a rocket scientist to figure out that all those people don't necessarily enhance safety, as was discussed here by other panelists.

At first glance, it seems that the Kraft report, which was released yesterday, does tend to agree with that assessment.

More importantly, I think we shouldn't put our human space program at risk every time a shuttle is launched. The truth is, no amount of money is ever going to be enough to really assure shuttle safety.

We all take risks in our lives. We all took risks getting here this morning. And, I believe that our tax dollars, we are used to taking risks with those as well.

We continue to send our sons and our daughters as volunteers to keep the peace and protect our national interests. And, I don't believe there is really any shortage of astronaut candidates at this time.

Frontiers are inherently dangerous places. When our country was settled, you had less than a 50/50 chance of making it.

If Queen Isabelle had been as concerned about shuttle safety as we are today, the Atlantic may yet to be crossed.

We will lose lives as we settle the frontier of space. And, we all have to accept that.

Of greater concern than risk, I believe, and they are intertwined, as Dr. Faget said, is cost. We support aggressive efforts to lower the cost of getting people and materials into space.

We are generally supportive of the innovative concepts that have been discussed here this morning, again some that were recommended in the Kraft report such as privatizing the shuttle and consolidating operations at KSC. More importantly, we support the X-33 and X-34 programs as first steps towards assuring long-term, cheap access to space.

We also recommend that more than one vehicle be pursued and that DOD continue its involvement in the reusable program. And, although it's outside your immediate jurisdiction, you might consider holding hearings with the National Security Committee to address the current policy of DOD investment in expendable technologies while NASA is given money to invest in reusable technologies, something that everyone feels is in our long-term interest.

I have submitted several documents in addition to my prepared remarks for the record, including some innovative procurement mechanisms such as a Mars prize and the results of the National Space Society's annual membership survey for your interest.

The editors of the "Time," I believe were right, that the space program that constitutes business as usual will surely fail. Where they were wrong was in their inability to imagine space activities that do not constitute business as usual.

And, we know that this Congress already understands that point. And, we urge you to put your shared vision into practice.

Thanks again for inviting us to testify.

[The prepared statement of Lori Garver with attached documents follows.]

NATIONAL
SPACE SOCIETY

TESTIMONY OF LORI GARVER
EXECUTIVE DIRECTOR, NATIONAL SPACE SOCIETY

MR. CHAIRMAN, MEMBERS OF THE SUBCOMMITTEE:

I would like to thank you, Science Committee Chairman Robert Walker, and the other members of the Science Committee and the Space and Aeronautics Subcommittee, for giving me the opportunity to testify today. You are hearing a great deal from experts at NASA and in the aerospace industry regarding the future of the NASA budget and of our nation's space policy. I would like to add some suggestions from the National Space Society, a grassroots organization representing tens of thousands of Americans who want to see a flourishing space program that produces real results, not simply jobs and contracts.

We at NSS are dedicated to the creation of a spacefaring civilization, by which we mean a civilization in which humanity lives off the Earth in a variety of settings on a permanent basis, and in which space travel is as routine and affordable as air travel. This is not only our goal, but the expressed goal of the United States government as well, as set out in the Space Settlements Act,[1] and in Bill Clinton's campaign position paper, and public answers to an Associated Press questionnaire on space issues. As evidence of the bipartisan nature of this goal, President Bush also endorsed it in his July 20, 1989 speech marking the 20th anniversary of the first landing on the Moon. So did President Ronald Reagan in 1988, when he declared that "America must lead the effort to colonize space, because in the next century leadership on Earth will come to the nation that shows the greatest leadership in space."[2] And, of course, House Speaker Newt Gingrich strongly endorsed this goal when he spoke at our Congressional space seminar here less than two weeks ago.

We stress this widespread support for our goal because there are still a few, mostly in the press corps, who find the idea of space colonization as a

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[1] Pub. L. 100-685, sec. 217; 102 Stat 4094; *codified at* 42 U.S.C. 2451 (1988) (declaring that "the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements," is a national goal, and requiring periodic reporting by NASA regarding how its programs are to advance this goal).

[2] *Quoted in* Lou Cannon, *President Salutes Discovery, Bush,* Wash. Post, October 15, 1988 at A4 Col.1. Former Supreme Court Justice William Brennan, Jr. has also endorsed the goal of space colonization, demonstrating that support for this goal is not only bipartisan, but extends across the usual liberal/conservative divide. *See* Justice William J. Brennan, Jr., *Space Colonization and the Law,* 3 HARVARD J. L. & TECH. 7, 12 (1990) (agreeing with Reagan quote and characterizing space colonization as an "inevitable" development that we should start preparing for now).

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national goal laughable. But it is not. Though such a goal may seem remote at the moment, we note that it is probably no more remote than the current intercontinental air travel system would have seemed in 1910.

. All goals remain remote, however, unless concrete steps are taken to reach them; it was recognition of this fact by Congress that led to passage of the Space Settlements Act mentioned above. We at NSS want to stress that this purpose, opening outer space as the next frontier, should serve as the overarching consideration against which all space policy and budgetary decisions should be weighed. From our perspective, promoting space settlement is the only overarching goal for the Space Station; all other purposes, such as earth observation, astronomy, and the generation of general scientific knowledge, are secondary. Our views are based on this perspective. I will discuss a number of issues in this light.

SPACE STATION

In short, we believe that the primary justification for the Space Station is that it will provide a place for learning more about living and working in space. This does not only mean the "life sciences" research needed to determine whether humans can survive extended periods of microgravity in the context of, say, human missions to Mars. It also means much more basic things like tool and spacesuit design, psychology of long-term space operations, life support technology, and so on. *The important thing is that Space Station capabilities, and plans for Space Station utilization, should be evaluated in the context of a long-term plan for developing the necessary skills to permit much larger-scale human presences in space down the line.*

In a recent editorial, the *New York Times* criticized the Space Station and the Space Shuttle as making no sense because we have nowhere to go after them.[3] In this, as is often the case, the editors of the *Times* were just about half right. The Space Shuttle and the Space Station *would* make little sense if we had no plans to go beyond them. But we do. The important thing is to ensure that our entire space program reflects those plans. And even in these times of strangled budgets, there are still things that we can do to promote progress toward the long term goal of opening the space frontier. The key fault in the *Times'* approach -- in this as in many things -- is its assumption that nothing significant will ever be done in space unless the government does it. But in fact, the Space Station should be viewed not as just another step in a long-term plan of purely government space activity, but as the opening wedge for large scale non-government activity in space. It will serve this purpose well if we pursue the proper policies over the next few years.

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[3] *Is NASA Among the Truly Needy?* New York Times, March 6, 1995 at A14 Col.1 (saying that "The station makes minimal sense unless it is part of a broader plan of space exploration -- a manned mission to Mars, for example, or a trip back to the moon for extended exploration or habitation").

As a grassroots group, we do not intend to wade into the mire of conflicting technical proposals. The problems with the Space Station program to date have not been technical, but managerial, and have stemmed from a sometimes unclear sense of what the station should be for. The explicit adoption of our goal in the Space Station design process would have solved many of these problems, and provided a clear touchstone for evaluating different technical proposals. It still can. Without entering the technical fray, we have a few observations and suggestions:

o In this post-Cold War world, given the economic problems faced by both the United States and the Russian Federation, cooperation makes a lot of sense. So does making sure that the Space Station is not hostage to superpower relations. Your subcommittee has played an important role in ensuring that that is the case.

o We should know our limitations. There is still a lot about living and working in space that we don't know. Thus, a Space Station design should be modular, or at least flexible enough to grow and change to accommodate our changing needs and wants as we move up the learning curve. It should serve as *the center of a growing civilian/commercial presence, not simply as the endpoint of a government program.*

o This means that *plans for the Space Station should allow for. potential commercial opportunities for station operation and servicing*. I am told that there is real industry interest in such opportunities, and commercial service in this context would not simply introduce greater efficiency into station operation, but would also promote the growth of an entirely new space industry sector, one that could find opportunities going far beyond the Space Station itself. This is particularly true as the private sector pursues plans for ambitious low-earth orbit commercial activities, like Iridium and Teledesic, that could make the on-orbit servicing market very important within a decade or two.

o In keeping with this approach, the government should consider selling the Space Station to the private sector at the end of its design life. Again, I can report that commercial interest in such opportunities is quite real.

o The station should be user friendly, and should accommodate people other than scientist/astronaut types. *Space belongs to everyone, not just a few civil-service thoroughbreds,* and recognizing this will help promote public involvement in the space program -- and help build a knowledge base for space settlement, since space must ultimately be settled by ordinary people, not just the highly specialized workaholics who constitute most space travelers today.

This last point is in many ways the most important. The space program belongs to all Americans. One reason why it has suffered in public esteem lately is that it has seemed an exclusive preserve of astronauts, bureaucrats, and contractors, leaving the American people feeling disconnected and distant. The money being spent on space programs belongs to the American people, not to the government and corporate officials who spend it. The program should serve the goals of Americans, not just the insiders. In overseeing the money that goes into the NASA budget, you should ensure that what comes out of it represents all Americans, by supporting a station that will develop capabilities that will eventually allow all Americans the opportunity to live, work, or play in space. A program that has that aim, and that pursues it credibly, will find political support easy. The editors of the *Times* were right that a space program that constitutes business as usual will surely fail. Where they were wrong was in their inability to imagine a space program that does *not* constitute business as usual. We know that this Congress already understands this point, and urge you to put our shared vision into practice.

SPACE SHUTTLE

One question that has come up a great deal in the context of NASA budget cuts has been the question of Shuttle safety. We certainly agree that the safety of the Space Shuttle is very important. But we do not believe that questions of safety should serve to cut off debate about the operations or uses of the Space Shuttle.

We are not a technical group, and cannot say whether it takes twenty thousand, two thousand, or twenty people to launch the Shuttle safely. But the size of the standing army currently supporting the Shuttle is very large indeed, and it is difficult to believe that it could not be trimmed without compromising safety. Certainly concerns about safety should not prevent us from examining this issue carefully.

We also do not believe that concerns about the safety of the Space Shuttle should make a difference in whether NASA flies private citizens in space. After the *Challenger* accident, concerns over Shuttle safety were cited in discontinuing the practice of flying teachers, artists, and so on on the Shuttle. This makes no sense. It represents the timid reaction of a bureaucracy frightened by the thought of bad publicity, not the product of a reasoned judgment of national needs, or of a proper appreciation of individual responsibility.

The Space Shuttle *is* dangerous, at least compared to staying home in bed. It is also a vital national resource, and an expensive one. If the risk of a Shuttle accident is too great for private citizens who voluntarily assume the danger, then it is too great to permit the Shuttle to fly, period. American citizens voluntarily undergo all sorts of risks, in sports ranging from football, to rock-climbing, to skydiving and snowboarding -- and in volunteer work on firefighting teams, rescue squads, and police forces. It is patronizing to say that the people who pay for the Space Shuttle are not adult enough to assume the risk of flying on it -- and it hardly makes sense to say that those who are not smart enough to make such decisions for themselves should nonetheless cough up the taxes to permit civil servants to assume the same risks. When he addressed our seminar, Speaker Gingrich called for "clean, simple zones of risk-taking." The public understands that space, like all frontiers, is risky. If people still want to go, then the government should not discriminate against them on that basis.

NASA should involve the public in spaceflight activities and restart the teacher-in-space program. NASA has set numerous deadlines for determining whether or not to resume the citizen-in-space-program but the issue remains unresolved. I call upon this Subcommittee to open a dialogue with NASA on this subject.

Risk, however, is not the biggest problem with the Space Shuttle. The biggest problem with the Space Shuttle is cost: it is much too expensive. That is a problem that the Shuttle shares with the rest of our space program: at the present cost of getting into space, we simply cannot afford to do the sorts of things that we want to do. For this reason, *NSS supports aggressive efforts to lower the cost of getting people and materials into space.* This does not simply mean putting money into a "Shuttle replacement." It means pursuing efforts to develop new ways of getting into space more cheaply, not just efforts to develop a single new vehicle. Indeed, we suggest (as we have suggested for several years) that a better approach for lowering the cost of getting into space is to avoid the one-big-program approach that produced the Space Station and Space Shuttle and do the kinds of things that the Vice President's Reinventing Government program has recommended: have the government do only what the private sector cannot easily do, which is to develop and test out new technologies, while letting the private sector put those technologies into practice. That is how we built the civil aircraft industry, and we believe that it is the way we will build a flourishing civil space industry as well.[4]

OTHER PROGRAMS

Although I understand that the Subcommittee expected me to speak primarily about the Space Station and Space Shuttle programs, I wish to point out briefly that the same long-term approach applies to *all* decisions about our nation's civil space activities. In making difficult budget or policy choices, the overriding question should always concern which approach does the most to foster the goal of opening the space frontier to large-scale human presence.

This approach applies not just to human, but to robotic missions as well. For example, if faced with a decision between two robotic space exploration missions, both of which produce good science, the question to ask is if one helps to promote human settlement of the space frontier more than the other. Thus, for example, the *Lunar Prospector* mission, which will produce detailed maps of lunar resources necessary for lunar (and orbital) settlement, comes out better than, say, a Pluto fast-flyby mission or another probe of Venus.

This long-term goal also suggests that we pursue other ways of setting loose the kind of energy needed to open the space frontier. For example, as Speaker Gingrich noted at our Congressional Seminar, the early aviation era was marked by the successful use of prizes to stimulate very rapid technological progress. Charles Lindbergh's flight across the Atlantic is the best known result of such prizes, but it is far from the only one.

Such an approach could profitably be used again -- either at the government level, as in the attached "Mars Prize" proposal, or at the private level, as some space activists (including NSS) are currently working on now. Or with a combination of the two, encouraging a full range of innovative efforts. An important role for your committee should be to explore such approaches, and where necessary to help remove roadblocks that might otherwise inhibit private efforts. Though government has much to contribute in opening the space frontier, it cannot do the job itself. We did not open the American West by having government employees build the Transcontinental Railroad, or by having enormous government-run collective farms plow the fertile fields of Iowa, Kansas, and California. Through such things as railroad land grants and the Homestead Act the government helped to promote these outcomes, but they were primarily the result of private efforts and private risks. Indeed, sometimes the most helpful thing that the government can do is to get out of the way.

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[4] For more on how this may be done see Glenn H. Reynolds, *Legislative Comment: The Omnibus Space Commercialization Act*, 20 RUTGERS COMP. & TECH. L.J. 581 (1994).

CONCLUSION

In this brief testimony I have outlined some important considerations for promoting our nation's future in space. This is a subject that the members of the National Space Society have been thinking about for many years. I am glad to be able to share some of the results of that thinking with you today, and would be happy to do more of the same in the future.

Attachments:

Space Policy Platform
Mars Prize Article
Ad Astra Reprint of Previous Testimony
NSS Space Policy Survey Results

NATIONAL
SPACE SOCIETY

National Space Society Policy Platform
February 1995

This document contains positions and guidelines on public policy matters affecting the goals of the National Space Society (NSS).

The vision of the National Space Society embraces the creation of a spacefaring civilization and the establishment of communities beyond the Earth. The NSS mission is to promote change in social, technical, economic, and political conditions to advance the day when people will live and work in space. We believe that the technologies and industries created on the space frontier will be of benefit to all humanity in the coming century. We believe that opening the space frontier will create new opportunities for human life, liberty and the pursuit of happiness.

Our goals include educating the public on the benefits of space development and working with allied organizations to create a supportive cultural and political environment for the exploration and settlement of space. We believe that opening the space frontier requires supportive public policies as well as technical advances.

Goals for Space Development

Spacefaring nations and organizations should conduct activities to: 1) obtain scientific, technical, and economic benefits for humanity and to improve the quality of life on Earth through space-related activities; 2) encourage private sector investment in space and related activities; 3) maintain the freedom of space for all activities that enhance the security and welfare of humanity; and 4) expand human presence in space beyond Earth orbit and establish communities throughout the solar system.

Pursuit of these goals requires several actions:

- lowering the cost of access to space
- learning how to work in space and use non-terrestrial resources
- ensuring supportive government space policies and practices
- fostering private space initiatives

Lower the Cost of Access to Space

Drastically lowering the cost of access to space is the single most important action towards accelerating space development. New initiatives should be encouraged from the civil, commercial, and military communities which require space transportation in accordance with the following principles:

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- As there are many promising technical approaches to improving current and future means of space transportation, research and development activities should be diversified with varying degrees of risk (e.g., including improvements to existing vehicles as well as next generation technologies).

- Emphasis should be given to developing and operating experimental flight test vehicles, such as proposed Single-Stage-to-Orbit concepts, in order to expedite decisions on the most promising approach to improving access to space.

- The pressures of market-driven competition are likely to be the most effective tool to lowering the cost of access to space, therefore the private sector should be encouraged to take a leading role in the routine operation of space transportation systems.

- Governments should be encouraged to support research and development of space transportation technologies, to be reliable customers of commercial transportation services, and to prevent unfair trade practices through international agreements. Minimize the burden of commercial launch licensing and ensure Federal regulations preempt State and local laws.

- In order to encourage market efficiency, the U.S. Government should consider chartering private launch service brokers to consolidate purchases of space launch services and provide attractive markets for new launch systems. U.S. commercial launch firms should be allowed access to government financing (e.g., Ex-IM Bank) when competing against international suppliers with comparable supports.

- The U.S. Government should encourage efforts by private organizations, State, and local governments to establish commercial spaceports, space launch ranges, and associated facilities on public lands that are compatible with existing uses (e.g., grazing, mining, and forestry).

- Space debris may pose an increasing threat to the safe use of Earth orbit. New technologies, standards, operating practices, and incentives should be encouraged to minimize the creation of space debris without placing excessive burdens on public or private space activities.

Learn How to Work in Space and Use Non-Terrestrial Resources

Establishing communities beyond the Earth requires learning new skills and developing new technologies in order to attain self-sufficiency. Even with lower launch costs, space settlements will require using non-terrestrial materials.

- An international Space Station should be completed in order to develop and demonstrate the means for people to routinely live and work in space on a permanent basis. Space construction, servicing, and repair tasks will require crewed, robotic, and teleoperated spacecraft. Evolutionary growth of Space Station operations should encourage the creation of multiple facilities in Earth orbit for public and private interests.

- Humanity should permanently return to the Moon as soon as possible. The establishment of scientific and commercial facilities on the Moon should seek the greatest possible degree of self-sufficiency using local resources.

- The Solar System should continue to be explored with both robotic and human missions. Priority should be given to missions with potential economic as well as scientific value. This would include, for example, missions to potential resource sites on the Moon, near-Earth asteroids, and the Martian moons.

- Concepts for solar power stations on the Moon and in Earth orbit should be developed for their potential to provide energy to space facilities and the Earth. Construction and operation of satellites and facilities should emphasize economic benefits, environmental acceptability, and the use of local resources.

- The skills and technologies developed by permanent habitation of Earth orbit and the Moon should be the basis for human expeditions to Mars. The potential terraforming of Mars should be studied with the goal of sustaining large-scale permanent settlements.

Ensure Supportive Government Space Policies and Practices

Government space activities have a major impact on the technologies, systems, and resources available for space settlement. Human expansion into the solar system should be assisted but not controlled by governments. Ensuring supportive government policies and practices will require sustained attention by the space community. Near-term initiatives should include the following:

- Create a high-level focus for space policy issues in the United States through the National Space Council. The Council should be strengthened to provide timely resolution of space policy and budgetary issues affecting the national security, civil, and commercial space communities.

- Require NASA to provide reports on activities supportive of space settlements as required by Congress.

- Provide support for key enabling technologies that have limited commercial markets at present, e.g., space nuclear power, life support systems, microgravity processing, non-terrestrial materials processing, and nanotechnology.

- Create prizes for space achievements as an alternative to traditional government R&D programs. Consider privatizing portions of current NASA and Defense Department space operations.

- Create voucher programs to allow government-supported researchers greater flexibility in their use of government or private aircraft, balloons, rockets, spacecraft, and related facilities.

- Require the government to seek commercially available space goods, services, and data to the fullest extent feasible in meeting public needs. The government should avoid actions that may preclude or deter private sector space activities.

- Provide greater protection for private sector intellectual property rights in government contracts and pay appropriate royalties and licensing fees in government procurements. These steps should lower the barriers between government and commercial industry sectors and encourage investment in entrepreneurial firms serving government markets.

- Streamline and reduce U.S. and international export controls on space goods, such as commercial communication satellites.

Foster Private Space Initiatives

Human expansion into the Solar System can not be accomplished by governments alone, but requires encouraging space commerce through private sector initiatives. The commercial space sector is currently driven by information technologies such as communication satellites, remote sensing, and satellite-based navigation. Fostering future initiatives requires a supportive legal and regulatory environment including reform such as the following:

- Reject the 1979 United Nations Moon Treaty and open discussions with signatories to the 1967 Outer Space Treaty and the 1972 Liability Convention on measures to speed the commercial development of space for all parties. These should include a legal regime recognizing private property rights and allowing "land grants" to reward space settlement. As a first step, create a U.S. Federal registry for private property claims on the Moon and other bodies in the Solar System.

- Provide tax exemptions for registered commercial space enterprise zones, space-manufactured products and space-based energy sources. Extend tax-exemptions for infrastructure bonds to include spaceports and space-based facilities. Allow investment tax credits for space research and development. Clarify tax regulations on intellectual property and intangible assets for major space investments.

- Encourage space exploration missions by private industry through government purchases of useful scientific data and non-terrestrial samples.

- Amend the Warsaw Convention on Passenger Liability to include human spaceflight and clarify the 1984 U.S. Commercial Space Launch Act's authority over such activities.

- Create a U.S. "space admiralty" court as part of a Federal district court to provide a specialized forum for the development of law and precedents for space commerce and communities beyond the Earth. Encourage reciprocal efforts by other spacefaring nations.

THE PRIZES

1. **The Challenge: To be the first to send a crew to Mars and return the crew members to Earth.**
   The Prize: $20 billion.
   The Conditions: A majority of the crew must be Americans. At least three crew members must reach the Martian surface and stay on the surface for at least 100 days. One or more members of the crew must make at least three overland trips of at least 50 kilometers from the landing site.
   The Bonus: In addition to the $20 billion, crewmembers will receive $1 million per person/day spent on the Martian surface, up to a maximum bonus of $5 billion.

2. **The Challenge:** To demonstrate the first system that can deliver 30 tonnes of payload to the Martian surface.
   The Prize: $5 billion.
   The Conditions: The demonstrator must make a soft landing exerting no more than eight g on the payload during any part of the trip.

3. **The Challenge:** To demonstrate the first system that can put 60 tonnes into a trans-Mars trajectory.
   The Prize: $3 billion.
   The Conditions: Hyperbolic velocity for Earth departure must be at least four kilometers per second. The system must be launched by a booster or boosters with a capacity of at least 120 tonnes to Low Earth Orbit (LEO) per launch. The booster must be launched from U S territory.

4. **The Challenge:** To be the first to demonstrate a system that can lift at least 120 tonnes to Low Earth Orbit
   The Prize: $2 billion.
   The Conditions: The booster must launch from U.S. territory Past history of the Saturn V is not eligible A revived Saturn V system is eligible

5. **The Challenge:** To demonstrate the first system that can deliver 10 tonnes of payload to the Martian surface.
   The Prize: $2 billion
   The Conditions: The demonstrator must provide a soft landing with no more than eight g experienced by the payload during any part of the trip.

6. **The Challenge:** To demonstrate the first system that can generate at least 15 kilowatts power (day-night average) for 500 days on Mars.
   The Prize: $1 billion
   The Conditions: A minimum of 2 kWe must be available at all times

7. **The Challenge:** To demonstrate the first system that can produce more than 20 tonnes of propellant on the Martian surface in the course of a 500-day stay on Mars
   The Prize: $1 billion.
   The Conditions At least 70% (by weight) of the propellant mixture used must come from Mars.

8. **The Challenge: To demonstrate the first system that uses propellants of Martian origin to lift a five tonne payload from the surface of Mars to Mars orbit.**
   The Prize: $1 billion
   The Conditions: At least 70% (by weight) of the propellant mixture used must come from Mars.

9. **The Challenge: To deliver a pressurized rover to Mars.**
   The Prize: $1 billion
   The Conditions: The vehicle must be shown capable of sustaining two humans on Mars for one week by means of a one week test conducted on Earth during which it is driven 1,000 kilometers over unimproved terrain. The vehicle must travel at least 100 kilometers on Mars. Cabin pressure during the Mars excursion must be maintained between three and 15 psi. The cabin temperature must be maintained between 10 and 30 degrees Centigrade.

10. **The Challenge:** To demonstrate a long-term life support system in space
    The Prize: $1 billion
    The Conditions: A crew of three or more must be sustained in space for at least two years without resupply from Earth

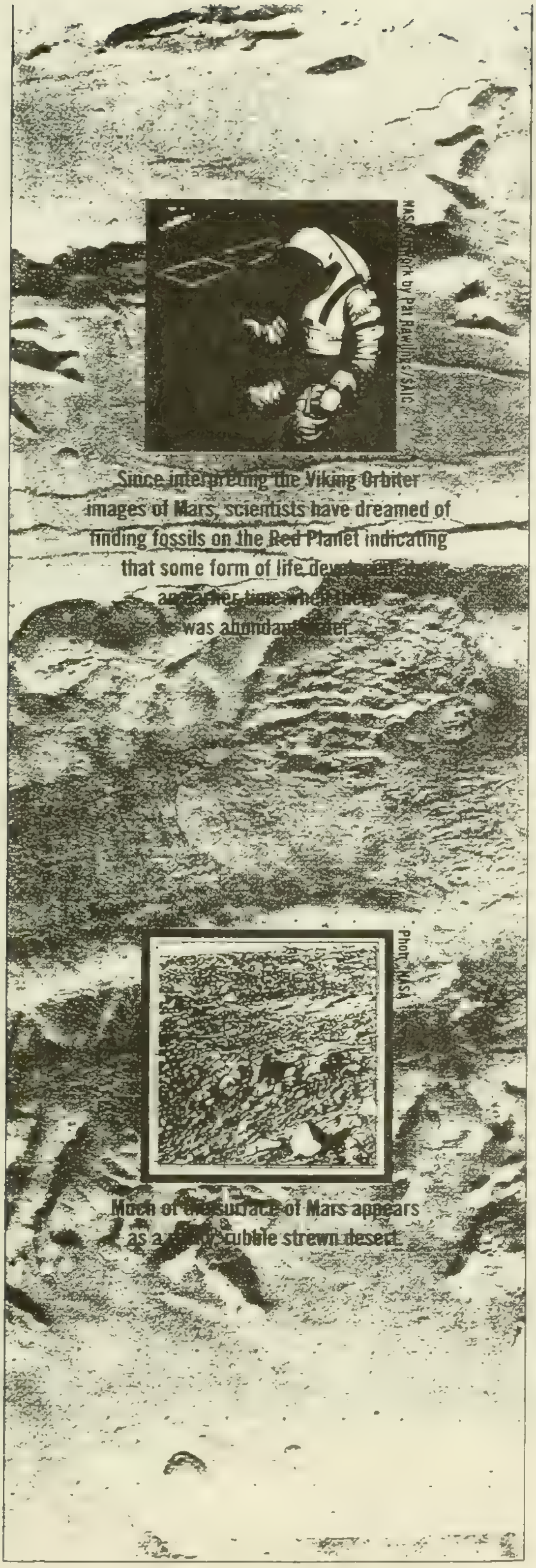
11. **The Challenge:** Accomplish a Mars Sample Return mission using propellants of Martian origin for the return flight.
    The Prize. $1 billion
    The Conditions: The sample size must be at least three kilograms At least 70% (by weight) of the propellant mixture used on the Mars ascent and Earth return legs of the mission must come from Mars.
    The Bonus: $10 million for each distinct rock type returned, up to a maximum of $300 million.

12. **The Challenge:** Accomplishment of a Mars Imaging Orbiter mission.
    The Prize: $500 million.
    The Conditions: The mission must successfully image at least 10% of the planet with resolutions of 20 centimeters/pixel or better All images must be made available to the U.S. government which will publish them.
    The Bonus. $1 million for imaging (with 90% coverage or better) each of 200 (100 kilometer x 100 kilometer) sites of interest selected by NASA's Mars Science Working Group

Total for all prizes and bonuses: $44.5 billion.

GENERAL CONDITIONS

Some general conditions would apply to all prizes since some of the challenges to be met encompass accomplishments covered by other challenges listed For example, any system that can deliver 30 tonnes of payload to the Martian



NASA artwork by Pat Rawlings/SAIC

Since interpreting the Viking Orbiter images of Mars, scientists have dreamed of finding fossils on the Red Planet indicating that some form of life developed at an earlier time when there was abundant water.

Photo: NASA

Much of the surface of Mars appears as a rocky, rubble strewn desert.

surface can also deliver 10 tonnes. If the more difficult mission is accomplished before the less difficult one, the organization performing the mission wins both prizes.

It would be required that at least 51% of the cash value of all hardware used to win any of the prizes must be made in the United States. This does not mean that every subsystem must be 51% U.S. made. For example, a successful mission to Mars using a Russian heavy lift booster can still claim the $20 billion mission prize, provided 51% of total mission hardware is made in the U.S.A, but that mission will not be eligible for the heavy lift launch system prize.

The winner of any prize would be required, at the government's option, and at a cost per copy no greater than 20% that of the prize, to sell up to three additional copies of the flight system used to win the prize to the U.S. government.

To support all missions competing for the prizes, the U.S. government would agree to provide the services of the Deep Space Network's (DSN) 34-meter diameter dishes at a cost to the user no greater than $20,000 per day. The U.S. government would further agree to provide support for all launches with the ground support and tracking systems available at the Kennedy Space Center and other potential launch sites and to lease land for launch pad construction to would-be competitors at these launch sites at reasonable rates.

RATIONALE FOR THE PRIZE SYSTEM SELECTED

The system of prizes detailed above provides the incentives required to launch a "Humans to Mars" program without risk to the taxpayer of cost overrun or program failure. While the total cost of the prize is only about one tenth the cost cited in NASA's 1989 90-Day Study on the Human Exploration of the Moon and Mars, the total amount is approximately equal to the 1993 NASA Johnson Space Center (JSC) estimate of cost for a government program based upon a variant of the leaner "Mars Direct" mission strategy.

This prize structure is proposed to allow an organization to build up the financial muscle required to assemble an actual human Mars mission that can win prize #1. Secondary prizes have been specified for the development of key subsystems or the accomplishment of key precursor missions that will facilitate the actual human exploration mission.

The "traditional" approach to human Mars missions, exemplified in the 90-Day Study, requires giant spaceships constructed in Earth orbit, supported by a large array of orbital infrastructure. The alternative "direct" approach, exemplified by the Martin Marietta "Mars Direct" mission plan, its JSC variant, and the Stanford University International Mars Mission Study, performs a Mars mission by flying payloads out to Mars using the "direct throw" capability of individual launch vehicles.

Studies to date have shown a very large cost reduction associated with such "direct" approaches. It is assumed, therefore, although not required, that private organizations competing for the prize will select such an approach. The primary requirement for a transportation system to support any human Mars mission is the ability to deliver payloads of about 30 tonnes to the Martian surface. If this is to be done by direct throw, a system capable of delivering about 60 tonnes

PRIZES OF THE PAST

Vin Fiz

In the Fall of 1911, William Randolph Hearst offered a $50,000 challenge to anyone willing to fly cross-country in less than 30 days. On 17 September, Calbraith Perry Rodgers accepted the challenge and left New York, bound for Los Angeles. His trip was sponsored by the Armour Meat Packing Co., which was expanding its market by promoting a new carbonated grape drink called *Vin Fiz*, the name Rodgers gave to his aircraft.

His less than successful journey lasted 84 days, survived 15 major accidents, and landed him in the hospital for a month after his engine exploded in Pasadena, California. Paid by the mile by Armour, Rodgers finally landed in Long Beach, CA., with only two of the original parts of his Wright-EX plane still functional. Despite his problems, Rodgers proved that transcontinental flights were possible.

The Gossamer Albatross

On 23 August, 1977, Bryan Allen completed the first controlled, human-powered flight. Winning the Kremer Prize of $200,000, Allen successfully flew the *Gossamer Albatross* more than one mile in a figure eight pattern. Less than two years later, he crossed the English Channel in the same aircraft, again making history as the first person to complete the trip in a human-powered aircraft.

onto a trans-Mars trajectory is required. Such a direct throw capability requires a heavy lift booster of at least 120 tonnes to Low Earth Orbit capability. Traditional mission plans based upon on-orbit assembly require a booster in this class as well. Therefore secondary prizes 2, 3 and 4, for the development of all of these primary elements of the Earth-Mars transportation system, have been included in the package.

While not necessarily required to accomplish a human Mars mission, numerous studies have shown a large potential for cost reduction and capability enhancement if the mission can "live off the land," making a significant portion of the crews' consumables and return propellants from materials that are readily available on Mars. This requires power generation on the surface, which is needed in any case for long-term life support. Prizes 6, 7 and 8 have been provided in order to facilitate the development of these technologies.

A pressurized rover, capable of traveling long distances over unimproved terrain is a key element if the crew is to have much mobility while on the surface. Prize 9 is provided to insure its development. Prize 5 is provided to facilitate development of a system capable of delivering 10 tonnes to the surface prior to the development of the more muscular delivery system mandated by prize 2, which calls for depositing 30 tonnes on the surface of Mars. An incentive to develop long-term life support, the remaining key technology for a piloted Mars mission, is provided by prize 10.

Two additional prizes are proposed to provide for the accomplishment of unmanned missions which can act as precursors to facilitate the piloted mission, as well as having a large science value in and of themselves. The first of these is the Mars Sample Return Mission using in situ propellant (prize 11). This mission would demonstrate a miniature version of the complete transportation and resource utilization system needed by the piloted mission. It would also provide a great deal of geological data which will be of use in planning the development of the Mars base technologies that will exploit resources found in the Martian surface materials.

The other prize, 12, is for a Mars Imaging Orbiter which will provide high resolution images (approximately a factor of seven improvement in resolution over that to be obtained by NASA's planned *Mars Global Surveyor* spacecraft). This will be very useful in selecting landing sites for the manned mission and planning long distance ground rover excursions.

In summary, it will be success in the field, not committee judgments, that will decide whose answers are best. The system of prizes provides the needed incentives to get humans to Mars and a financial "runway" that will allow private organizations to accumulate the capital required to finance such a venture through a series of lesser demonstrations of the critical technologies required to meet the major program challenges.

The prize system does not prescribe the design of the mission; no-one is obligated to go for all or any of the lesser prizes in their quest for the grand prize; it is a "runway" with multiple entrances. Each organization competing will be able to use its own creativity to determine the most efficient path to the final goal.

CONCLUSION

The planet Mars has a surface area as large as the land area of the Earth. It contains all the elements needed to support human life. Provided that appropriate technologies are developed, those elements can be transformed into resources that will allow Mars to become home for a new branch of human civilization.

Four hundred years ago, the leaders of Tudor England seized the moment and conceived plans for the spread of civilization into the New World. We who live in the New World look back in wonder upon them. Four hundred years from now, humans will live not just on the Earth, but on many worlds in this neighborhood of the galaxy. Let us take action now, so that four hundred years from now, they will wonder at us. ☆

A Space Program for the Rest of Us

Executive Director Lori Garver carries the NSS word to the Hill.

NASA's 1995 budget marathon lurched off the starting line this past February as administrator Dan Goldin appeared before the Subcommittee on Space of the U.S. House of Representatives Committee on Science, Space and Technology. Goldin wasn't the only witness for the day, though. NSS Executive Director Lori Garver had been invited by the subcommittee to testify in support of American space programs and, given the occasionally testy comments by some members of the subcommittee, positive words on space were what the subcommittee needed to hear.

Goldin presented President Clinton's fiscal year 1995 (FY1995) budget request of $14.3 billion for NASA—$250 million below the FY1994 appropriation and the first reduction in the NASA budget since 1974—as a "budget plan that reflects the economic challenges and fiscal realities America is facing today." Those realities are pretty dim, considering that NASA absorbed an 18 percent cut in real terms in its five-year FY1994 budget submittal, and a 12 percent cut in the five-year FY1995 budget presented before the subcommittee. That's a 30 percent cut in NASA programs through FY1999 over the course of just two years.

From the outset, several subcommittee members expressed doubts about Goldin's claim that NASA could support "a balanced space and aeronautics program" with a decreasing budget. (The Congressional Budget Office came to similar conclusions some weeks later, see Mission Control, Resources*). However, these doubts paled beside some of the broadsides delivered against the space station.*

Rep. Dick Zimmer (R-NJ), commenting on the revised space station, said that the station "used to be a jobs program for America," but now was "looking more and more like a jobs program for Russia." Subcommittee members charged that Goldin still could not tell them what the space station would cost, when it would be operational, or what it would look like—yet the project had already cost $11 billion over 10 years and had been through six redesigns. The fact that the latest space station design did not even have a name led Zimmer to suggest, "Perhaps we should rename it space station Svinina—that's the Russian word for pork." Rep. Jennifer Dunn (R-WA) voiced her concern that heavy dependence on Russian infrastructure and transportation could turn the the U.S. space program into a "time-share space program."

Warning that further budget cuts would likely be inflicted by the appropriations committee, subcommittee members questioned NASA's proposed shuttle flight rate of eight launches per year. NASA's Gen. Jeremiah Pearson noted that studies show that some savings can be obtained and safety standards maintained if the flight rate is reduced to six shuttle launches per year. However, any further reduction in the flight rate would threaten safety standards and would show only limited financial savings because of the inherent costs involved with shuttle launches and human spaceflight.

Garver's testimony on behalf of the Society followed Goldin's remarks. In her comments, she offerred a neat summation of the objectives of the National Space Society and space advocates, offering much-needed vision in the midst of the usual stürm und drang of a Capitol Hill hearing. The text of her testimony follows.—P.D.

Mr. Chairman, members of the subcommittee, thank you for inviting me to be here today and for allowing me to represent the views of members of the National Space Society before this subcommittee. You have asked me to describe the policy choices that Congress may need to consider if significant funding reductions for NASA are made in the remainder of the budget process. I will do so, but first wish to set out some background to explain why we take the positions that we do—and why we believe that the United States Congress should share our views

The National Space Society is a grassroots pro-space organization with over 25,000 members in the United States and abroad. Formed by the merger of the L-5 Society and Wernher von Braun's National Space Institute, it is the oldest pro-space group in America. Our vision is basic: that the exploration, development and settlement of outer space will allow the continued material and spiritual growth of humankind. Our goal is simply stated: the creation of a spacefaring civilization, at the earliest possible time.

What do we mean by a "spacefaring civilization?" We mean more than simply a civilization that sends occasional missions, piloted or unpiloted, to other locations within the solar system. Rather, we mean a civilization in which space travel is *routine* and *affordable*—as air travel is today, for example.

But we mean even more than that.

We seek a civilization in which space is a place to do humankind's business: developing resources, living and playing. This should be the central purpose—the destiny—of the U.S. space program.

Obviously, we will not create such a civilization overnight. But doing so is well within the realm of possibility and seems far less remote today than, say, a global air-travel system would have appeared in 1910. Indeed, our goal is not only reasonable, but is one we share with President Clinton and with the Congress—both have declared that the expansion of human settlement throughout the solar system is a major goal. We agree, and believe that expanding beyond the surface of our planet is the only way to deal with long-term population, energy and environmental problems.

Our perspective is, we believe, uniquely representative of the informed segment of the American public. Interest in space among the American people is strong—as demonstrated by the popularity of space themes in commercials, television shows and children's toys. It is no accident that *Star Trek: The Next Generation* is the most popular television show in syndication, or that space shuttle launches and landings consistently attract enormous crowds. But this *interest* on the part of Americans is not generally matched by *knowledge* about the space program. According to a 1986 Market Opinion Research study, 67 percent of the American people believed that space absorbed between 5 percent and 50 percent of the federal budget; an amount ranging from three to 25 times the true percentage. And relatively few Americans—only about 12 percent of adults according to a recent study—closely follow the doings of the United States space program. Thus, references to public opinion on the space program are generally references to *uniformed* public opinion.

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On the other hand, the opinions of the National Space Society's membership represent that segment of the population that follows the space program regularly and is well-informed as to the realities of both budgets and technology. We believe that our views as to what a space program is ultimately for—the facilitation of human expansion off this planet, a goal shared by the Congress—and how to serve that end should be of particular interest.

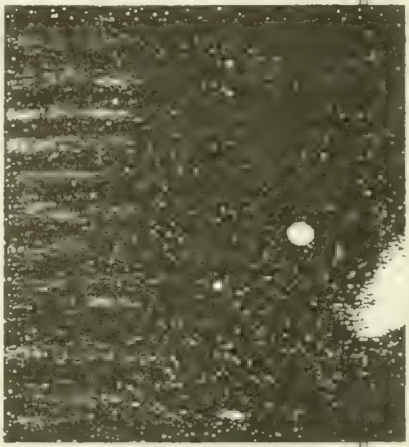
A Space Program for the Rest of Us

If the major long-term goal of our space program is to facilitate the creation of a spacefaring civilization, what should its priorities be today? We believe that such priorities should include: lowering the cost of getting into space; learning how to live and work in space and developing a knowledge base regarding the resources that are available for use in outer space. A space program based on these priorities would spend substantial amounts on research and development aimed at lowering launch costs and improving launch vehicle reliability; on-orbit experimentation aimed at helping people learn to build things and operate in space; and lesser but still significant amounts on scientific missions aimed at developing knowledge about Lunar resources, near-Earth asteroids, orbital solar power generation and related issues.

How does the current program stand up in light of these factors? Not terribly well. Although we spend a substantial amount on space transportation, nearly all of it is for space shuttle operations, not for research and development aimed at lowering launch costs. A program that served the important national goal of facilitating lower-cost access to space would invest far more in research and development and spend substantially less on operations. At the moment, everyone agrees that our national launch capability is in trouble, threatened by outdated technology and excessive costs. But little is being done to address this problem, and programs—such as *Delta Clipper*—that are aimed at solving it have become a focal point for political sniping by those with an investment in the current way of doing business.

Regarding efforts to learn about living and operating in space, we are doing somewhat better. Some space shuttle missions have explored this issue, and the planned U.S./Russian space station will provide an adequate facility for many such efforts. However, the United States should begin making more use of the *Mir* facility for such efforts in the short run, and a better conceived program of space experimentation would make more use of space shuttle flights for these purposes as opposed to other research.

Our scientific data-gathering constitutes another weak spot in our current program, when viewed from the perspective of whether it helps to create a spacefaring civilization. NSS believes that the primary importance of robotic exploration is as a precursor to human exploration. Just as specialized exploration missions—like those of Lewis and Clark or Zebulon Pike—preceded human settlement of America's west, so robotic missions should have the primary purpose of gathering data that will facilitate later human exploration and settlement. Judged by this standard, many current missions are unsatisfactory.



Some critics of human exploration seem to believe that the only legitimate purpose for robotic missions is the gathering of pure scientific data, unconnected with any later human missions. While NSS certainly has no quarrel with the gathering of scientific data (and we note that "abstract knowledge" often turns out to have concrete uses in the end), we would not consider a world in which everything was known about the solar system, but in which no human left the surface of the Earth, to be an acceptable one. Such a world might be acceptable to some (though certainly not all) planetary scientists, but we must note that their opinions are hardly objective, given the tangible rewards—such as tenure, research money and professional standing—that flow from the robotic missions they champion.

NSS recommends a broader view. While learning about our solar system is worthy in itself, the greatest returns to humanity as a whole will come only if that knowledge is put to use in a more concrete way—to further the goal of human settlement beyond the Earth. Only in this context does a truly major commitment to robotic planetary exploration make sense. Human exploration and robotic exploration must go hand-in-hand, notwithstanding the all-too-popular view that they should be thought of in either/or terms. In fact, "either/or" thinking on this topic is unlikely to help the cause of robotic exploration: If human exploration and expansion are given a low priority, it then becomes more difficult to make a strong case for robotic missions as well, given that other competitors for research dollars—biomedical research, for example—might then arguably have a stronger claim to improving the human condition than would the abstract knowledge generated by robotic planetary missions The result would be a disaster for the space community as a whole, and for humanity. For this reason, we oppose treating robotic exploration as somehow separate from, and independent of, human exploration and settlement. We believe that missions should be designed not simply to produce knowledge that is valued by scientists for its own sake, but knowledge that will be of concrete use in support of human settlement activities down the line.

The space program belongs to all of us—even, in a special sense, to future generations—not simply to the astronauts, scientists and contractors who are involved in it on a day-to-day basis. Although many Americans would like to visit space themselves, even more would like to see a future in which their children and grandchildren will be able to do so. And all of us would like to see a future in which Earthbound problems of environmental decay, energy shortages and overpopulation are eased by space settlement and the use of space resources

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Programs and Priorities

In looking at the proposed budgetary figures, it is difficult to escape noticing that the two biggest line items are space shuttle operations, at $3.3 billion, and space station, at $1.9 billion. Because the United States is largely locked in to the space station by existing international agreements, it is tempting to look at space shuttle operations costs as a place to save money. The main argument in favor of making cuts there is that shuttle operations by themselves do not do much to contribute toward a spacefaring civilization, unless they involve flights that involve experiments or activity that are aimed at learning how to live and work in space.

There are some problems with this approach, however. First, cutting shuttle flights will not necessarily save very much money—a large part of the space shuttle operations budget is eaten up in fixed costs. Second, trying too hard to reduce costs may result in safety and reliability problems that will wind up costing enough to outweigh any "savings." Nonetheless, we believe that serious attention should be given to the question of reducing the share of the total space budget that is eaten up by space shuttle operations. As the vice president's Space Policy Advisory Board put it, "The shuttle is very expensive relative to its role in the U.S. space program. Hardware procurement and personnel levels required to support shuttle refurbishment and reflight result in over 35 percent of NASA's budget (about $5 billion per year) being devoted exclusively to shuttle operations to support only seven to eight flights per year."

Although we recognize that there are substantial technical and organizational barriers to reducing shuttle operations costs, we believe that such an effort is essential. Although we agree with the vice president's Space Policy Advisory Board that "[T]he Shuttle has a unique and important role in manned space flight for the United States and … is inextricably tied to space station operations into the next decade," we also agree that "some solution to its high cost must be found." Certainly we believe that as the highest cost part of our space budget, shuttle operations should bear a substantial proportion of efforts to reduce that budget. But we need to pay attention to the long-term as well.

At the very least, we believe that we should be investing more money in efforts to lower launch costs. One possibility that your subcommittee should consider is a launch cost "tax" on government space operations. In short, spending equivalent to some predetermined percentage of launch costs could be earmarked for research programs aimed at lowering launch costs. Such an approach would prevent high current-term launch costs from eating up our technological "seed corn" and preventing investment in technologies and operational methods that could lower launch costs substantially over the medium- and long-terms

In the context of space station, we have consistently argued that any U.S.-supported space station should be focused on developing capabilities that will lead to long-term human habitation in space. To be frank, we are not entirely certain how well the current cooperative station will meet this requirement, as its design remains in flux. However, we believe that the cooperative venture will probably produce more benefits along these lines (quite possibly at lower cost) than would otherwise be possible, and will have a number of ancillary benefits as well. We thus do not believe that this program would be a suitable subject for significant budget cuts that might derail its progress.

Why Space?

Although your invitation did not specify this question, I would like to address one additional issue that is likely to come up at some point during this year's discussion of NASA's budget: Why spend money on space at all? That is, in a time of fiscal constraints and diminished horizons, why spend money on space when it could be spent on other things, such as veterans' benefits, toxic-waste cleanup or welfare?

There are a number of answers to this question, but all of them boil down to this point: Space represents our future, and if we do not invest in our future, we will inevitably suffer in precisely the areas that other spending programs—like those mentioned above—are meant to address.

Essentially, all federal spending can be divided into consumption and investment items. Both are important. A nation that consumes too little—Japan, for example—has an impoverished existence despite its wealth. A nation that spends too much on consumption and invests too little in the future—Great Britain, for example—gradually falls behind its competitors. If America is to enjoy the wealth it will need to address the problems of the 21st century, it must be strong in the areas that will be important in that century, of which space is surely one of the most important. So space is an investment program, and we must be sure that we invest enough in it, and that the money that we invest is invested wisely. Taking money from investment programs, such as space, to fund consumption programs, such as welfare, is akin to eating our seed corn. It promotes present day consumption at the expense of future well-being.

Why is space an important investment? Because we live on a planet that is steadily shrinking, both in terms of its resources, and in its ability to absorb environmental damage from a steadily growing world population. So long as we remain limited to one planet, we have no hope that humanity will prosper over the long term—no matter how carefully we conserve our resources, if the supply is limited, we will eventually run out. Investment in space development and settlement is the only way to break out of the "closed system" and make use of the virtually unlimited resources of the solar system, ensuring a prosperous future for humanity. This is not merely visionary folderol. As Gregg Easterbrook, a Washington journalist usually regarded as hardheaded, writes:

Today we regard the living shroud around Earth and speak as though that were nature. Look up over your head some evening. Earth is one-zillionth of a zillionth of nature. Environmentalists admonish that the only way to understand the environment is to remember that everything is a part of everything else. Then they speak as though Earth's ecosystem were a closed system, a be-all and end-all. It is but a tiny part of a vastly greater natural scheme."

Space development will allow us to gain access to a much larger part of the "natural scheme." If space development is pursued, by the end of the next century we will have access to all the material and energy wealth of the solar system. Access to that wealth (along with the banishing of many dirty processes to locations outside the Earth's biosphere, where they can do no harm) will allow us to lift the world's poorest nations out of poverty without destroying the Earth's environment, and will thus allow us to avoid wars, overpopulation and other problems that would otherwise be bred by scarcity.

This is what makes investment in space development unique. No other claim on U.S. government resources has the same potential to convert a future filled with scarcity, conflict and environmental destruction into a future filled with abundance, peace and environmental preservation. Space programs that contribute to the permanent settlement and development of outer space are qualitatively different from consumption programs that offer temporary amelioration of current-day problems.

That is not to argue against programs that offer present-day benefits, as such programs are clearly necessary and justified. It is simply to point out that such programs do not offer the kind of long-term potential that space programs possess. Focusing solely on consumption programs to address present-day problems while ignoring investment programs that offer

1995 National Space Society Member Space Policy Survey Results

03/14/95 8:59 AM

Question 1.

One of the most difficult, and most important, questions confronting U.S. policy makers concerns the "why" of exploration - why explore? Please tell us the three reasons you believe that space exploration and development are most important (number your choices 1, 2, and 3)

1. Further technological development
2. Expand settlement frontiers
3. Improve the Earth's environment
4. Foster commercial opportunities
5. Promote international cooperation
6. Create high-tech, high paying U.S. jobs
7. Enhance U.S. international economic competitiveness
8. Stimulate interest in math/science education

Question 2.

Imagine yourself as a freshman Member on the House HUD, VA and Independent Agencies appropriations subcommittee (a key committee for NASA). You are given a mythical $100 to allocate to the following space projects. How would you divide it up?

New low-cost launch system to replace shuttle	$19.75
Space Station	$15.41
Return to the Moon and establish a permanent settlement	$14.58
Mars Exploration	$10.93
Mission to Planet Earth (environmental research)	$ 7.36
General space science and technology research	$ 6.53
Support of space commercialization	$ 6.33
Distant planetary science missions (e.g. outer planets)	$ 5.95
Solar Power Satellites	$ 5.07
Robotic exploration of the Moon and asteroids	$ 4.52
Search for Extraterrestrial Intelligence (SETI)	$ 3.25
Other Interests	$ 0.32

Question 3.

The United States and Russia have increased their government-to-government space activities, most notably in the space station program. Many are concerned that given the current lack of political/economic stability, the Russians are an unreliable partner, and that the inter-governmental agreement to build the space station should be scrapped. Others argue that involving the Russians in the construction of the space station is, in itself, a stabilizing factor, and, therefore, is good economic and strategic policy. Do you feel that the space station should be redesigned again to diminish or eliminate Russian participation?

Proceed as designed	87 %
Redesigned to further limit Russian participation	08 %
Redesigned to eliminate Russian participation	03 %
Unsure	02 %

Question 4.

Both from within government and without, NASA has heard many calls to change its way of doing business. Most observers agree that NASA is proceeding, albeit with some difficulty, with overdue reforms. How would you rate NASA's progress on implementing the reforms? Or, do you feel that NASA is beyond reform and should be scrapped in favor of an entirely new entity?

NASA is doing a *fair* job implementing reforms	55 %
NASA is doing a *poor* job implementing reforms	18 %
NASA should be eliminated in favor of a new federal agency	12 %
NASA is doing an *excellent* job implementing reforms	07 %
Unsure	08 %

Question 5.

NASA, the Department of Defense, international space agencies and private commercial firms all launch and operate spacecraft today. Look ten years into the future. Please rank the following entities' importance as drivers of space activities over the next ten years. (1 = most important)

1. NASA
2. Private, commercial space firms
3. European Space Agency
4. Department of Defense
5. Russian government
6. Japanese government
7. Private space organizations (NSS, Planetary Society, etc.)
8. Chinese government
9. Other Asian-Pacific governments (Australia, India, Taiwan, etc.)

Question 6.

A principal reason that NSS launched its "Return to the Moon" initiative is to focus national attention on various proposals to accelerate the pace of space exploration and development. Of the five proposals listed below please indicate which initiatives you believe would do the most to accelerate the development of a spacefaring civilization. (Select the three best and rank them 1, 2, and 3)

1. Cheap access to space
2. Broader public understanding of *-and support for-* space exploration and development
3. Greater involvement of private enterprise
4. Demonstration of a valuable product manufactured in or obtained from space
5. More government funding for space and international space cooperation

Question 7.

We are hopeful that this Congress may be more supportive of commercial space initiatives than previous ones. Which of the following proposals do you feel would be the most effective legislative approaches for Congress to promote commercial space activities? (Select the three best and rank them 1, 2, and 3)

1. Eliminate obstructive or unnecessary government regulations
2. Increase government R&D contracts to private industry for new space technologies
3. Privatize as many government space activities as possible
4. Eliminate direct competition between government and private industry
5. Offer limited tax exemptions for products developed in space
6. Provide federal subsidies and /or tax breaks to space firms competing internationally
7. Offer federal cash prizes for space-related achievements
8. Establish a quasi-federal space development bank

Question 8.

Space tourism is being touted by some as one (if not *the*) avenue to open the space frontier. If is were possible to book passage on a vehicle and spend two nights on an orbiting hotel, would you check in with your travel agent, and if so, at what cost for the entire package?

Yes, if the cost were less than $5,000	47 %
Yes, if the cost were less than $10,000	35 %
Yes, if the cost were less than $50,000	08 %
No, not at any price	08 %
Yes, if the cost were less than $100,000	01 %
Unsure	01 %

Question 9.

This year, 1995, is the deadline given by the U.N. for member nations to ratify the Moon Treaty. The Moon Treaty would ban private or national ownership of the Moon's resources, treating it as a resource for all humanity, similar to the international laws which govern the Antarctica. NSS opposes the treaty on the grounds that the denial of private property rights will prevent private commercial development of the Moon, the best hope for a spacefaring civilization. To date, the U.S. Senate has ignored the treaty. How should NSS respond during this, the final year of the Moon Treaty ratification?

Continue the current policy without Senate consideration	43 %
Demand Senate take up the treaty, and vote it down	30 %
Disagree with the NSS position, ratify the treaty	23 %
Unsure	04 %

Question 10.

The National Space Society represents itself as a national citizens organization for pro-space advocates. What actions, if any, did you undertake during 1994 to promote space exploration and development? Please check all that apply.

Wrote a letter to the editor	06 %
Wrote a letter to my Representative/Senator/President	32 %
Phoned a radio/TV talk show	04 %
Financially supported a NSS special initiative	57 %
Recruited one or more new members to NSS	06 %
Completed and returned the 1994 Space Policy Survey	77 %
None of the above	10 %

Mr. SENSENBRENNER. Thank you very much, Ms. Garver.

I have a couple of questions of Mr. Parmet, who is more of our safety expert than the other members on the panel. As you know, Mr. Parmet, last year the shuttle and the station accounts were combined in the NASA budget.

And, the fear that was expressed by a number of members of the Committee, including myself, was that that made the shuttle budget the insurer against cost overruns in the station. So, if the station had a cost overrun, it would come out of the shuttle and everybody could smile, saying that there was no extra money that was needed because everything was fine.

We were concerned at the time that that compromised shuttle safety.

Secondly—and this is somewhat similar, but I would like you to answer these questions together if you could—is that with the apparent move toward privatization of the shuttle and the operations of the shuttle being under one contract that would be out, I would guess, for bids with the major aerospace firms, do you think that having a prime contractor would pinpoint responsibility for safety; and, thus, there would be a better job done on safety than with the current diffused situation?

Mr. PARMET. That's a mouthful. First—

Mr. SENSENBRENNER. I have five minutes, too.

[Laughter.]

Mr. PARMET. Let me answer the first part first. I have not seen any compromise in the way the shuttle program has been handled as a result of the space station costs.

There may be some. But, I don't think they are visible. They are certainly not visible to us.

With respect to the second part, privatization, I have some concerns about that. NASA has a tendency when they contract something with any commercial industry is to tell them how to do it and then keep telling them how to change it.

And, unless NASA sets some ground rules for how a private organization will work to produce the shuttle and establishes a capital program for assuring that continued improvements occur in the program, I think you can have a mishmash of things with the finger-pointing going on when something goes wrong, "Well, NASA didn't give us the money for this," or, "They interfered with what we were doing."

So, if there is a privatization program, it has got to be clearly defined as to what that private contractor would be doing and held responsible for that. And, NASA, as long as that—should audit what is being done but should not interfere with the way the organization works.

Otherwise, it's going to be worse than today. Is that a fair answer?

Mr. SENSENBRENNER. That's a very good answer. And, I appreciate your stating it for the record.

The gentleman from Minnesota, Mr. Luther.

Mr. LUTHER. Thank you, Mr. Chairman. Mr. Parmet, I had a question for you as well.

And, that is whether you would comment briefly on the suggestion that was made by Dr. Faget concerning the possible—or the potential for cutbacks in the safety area. I don't know that you addressed that to the extent that he did, whether that could be done without compromising the situation.

If you could, comment on that, please.

Mr. PARMET. Well, it's being done today. If you think back, the Rogers Commission imposed a hell of a lot of hard requirements on NASA.

And, NASA over-responded, in my view. As a result, there was a quality function created where there was none before.

And, yes, I think there is a lot of areas where quality inspection—where quality control can be done in different ways. And, it certainly can be reduced in scope.

In fact, at the Kennedy Space Center, there just was a reduction, which is a fair percentage of the QA people down in Florida. But, it's not a large number of people. It's about 50 people that were dropped from the program.

And, I think you will see more and more of this as programs such as I mentioned before, structured surveillance, spread out inside of NASA to the point where you get rid of unnecessary inspections, because they don't give you anything. In fact, they create more problems at times.

So, get rid of the unnecessary stuff but stick with the important things. And, that's going to take some thinking.

Is that an answer to you?

Mr. LUTHER. Yes. Thank you.

Mr. SENSENBRENNER. The gentleman from Florida, Mr. Foley.

Mr. FOLEY. Thank you very much, Mr. Chairman. The first question is for Ms. Garver.

Would you elaborate a little bit on the Department of Defense's and NASA's capabilities together?

Ms. GARVER. Yes. I think what we have now is a White House policy that separates reusable technologies and gives it to NASA for launch and expendable technologies to the Department of Defense.

Clearly, a lot of people like this policy, because past efforts at doing a joint program were not successful. However, I think when we have a reduced budget like we do now, we've got to be successful, maybe not at a joint program but on a focused effort in determining what type of technologies we want to have for space transportation.

Clearly, reusable space technologies are the future. There is no other area of transportation where we throw away the vehicle after we use it.

And, in space we should ultimately have no difference. If we aren't there yet, let's look at two-stage reusable.

But, I think it is not a very efficient use of our money to have the Department of Defense proceeding on a totally unique path to NASA in upgrading ELVs. And, there is quite a lot of money being spent in that area.

Mr. FOLEY. Is this specifically like Star Wars? What are we getting at?

Ms. GARVER. It's a space transportation system. The payload would be Department of Defense.

They are looking at launching satellites. This is not specifically tied to Star Wars or what is now called the Ballistic Missile Defense Organization.

Space transportation was taken out of that organization. And, that was a reusable system actually which they gave to NASA.

Now, we have only the expendable technologies existing in any real way within the Department of Defense. And, they are to follow on for the Titan, the Atlas, the Delta, those vehicles.

Mr. FOLEY. Okay. Thank you. Mr. Parmet, are you aware of any internal assessment made of the shuttle schedule required to support station assembly?

Mr. PARMET. I'm aware of what the schedule has been. I'm not aware of what this reduction in staff will do to that program.

There's some very tight scheduling that was planned. And, I think it's going to be disrupted by such a reduction.

It's also going to be disrupted, in my opinion, by the fact that the Russians won't deliver some of their portions of the space station on the schedule that was originally envisioned. In fact, I was just advised today that Specter is going to be a month late. And, that's part of a June launch which now has to go into July.

So, you are going to face things like that as you go along.

Mr. FOLEY. Well, if the Russians fail to deliver, where do you see our role?

Mr. PARMET. We have to defer the flight that involves a Russian piece of equipment. Now, there may be valid reasons why it's delayed.

It may not be finished or they are not satisfied with it. But, in any event, you are going to lose the flexibility that you have today if you cut your staff to the bone.

Mr. FOLEY. Okay. What will the impact be on the space station and the space station budget if a shuttle launch fails to go on time?

Mr. PARMET. Well, I have to say, just like any program, the more you delay it the more it costs you. I don't have a specific answer.

But, that's sort of axiomatic with things in the past.

Mr. FOLEY. Dr. Faget, you mentioned or at least commented that efficiency, safety, all of those are very intertwined. To make it more efficient, you risk safety; or to increase performance, you risk safety.

How do you get to a happy medium to provide for all of the above without jeopardizing lives or substantial investment?

Mr. FAGET. Well, what I was leading up to is that I believe that if we try to improve the performance, which can only be done by reducing the weight or getting more thrust out of the engine—if you run the engine for a higher thrust, you normally increase the risk of a catastrophic failure. If you reduce the weight, you are going to increase stresses.

Now, you can use higher stress material. But, these higher stress materials are not proven materials in all cases.

So, anyway you look at it, it's a bigger risk. My opinion is that what we should do for those payloads that require this heavy weight that have to go into the high inclination orbits should be flown on an unmanned shuttle.

We take the crew out of the shuttle, all our equipment, all the particular expendables and so forth, and you can get 12 thousand pounds out of that shuttle and solve all the problems. Meanwhile, we can maintain the shuttle as it's presently configured and concentrate on improving safety and reducing costs. That's what I would do.

Mr. SENSENBRENNER. The time of the gentleman has expired.

The gentleman from Kansas, Mr. Tiahrt.

Mr. TIAHRT. Thank you, Mr. Chairman. Dr. Mark, you talked about the pseudo public/private corporation of COMSAT.

Right now, as I understood, there's about three thousand NASA employees and about 27 thousand contractors. How would that mix change if we went to some type of a public/private corporation?

Mr. MARK. The model that I would advocate, Mr. Tiahrt, is that NASA employ a single contractor for the entire operation of the space shuttle transportation system. It has been pointed out by other witnesses here that there are now 20-odd contractors involved in the operation plus a civil service work force.

What you would have is a single contractor. The people who run the shuttle would all be employed by that contractor. In addition, it is terribly important to manage this contractor in such a way that the government is not micro-managing what the contractor does, so that the contractor is incentivized to operate this thing in the best way possible. And, we've already talked about safety and cost and all these things.

The best way possible—and the incentive, of course, would be award fees, would be money. I think we have done that successfully in the past with many systems.

If you look at how the Air Force operates the Titan vehicle, for instance, it is done entirely through a single contractor. I think we can do the same thing with the shuttle.

Mr. TIAHRT. You are saying that the one contractor would be kind of an integrator and then it could subcontract to some other—

Mr. MARK. I'm sure that the contractor would subcontract certain parts out. But, again, that's something that I would leave to the contractor.

The main point is that the government would have a single point of contact, a single organization, with which to work to operate and fly the shuttle.

Mr. TIAHRT. Thank you. Ms. Garver, you talked about potentially combining some of the research between the Department of Defense and NASA for reusables.

What do you see—or what does your group see as kind of the next step or the next generation to get a reusable? Is it propulsion? Is it aerodynamics?

What do we need to pursue?

Ms. GARVER. I think both of those technologies are important to pursue. And, NASA is now pursuing those.

What I'm recommending is that the Department of Defense continue to actively pursue reusable technologies as well. We need materials. We need propulsion. We need X programs like the X-33 and X-34 and the DCXA, which right now the Department of Defense is finishing up.

We think there should be follow-ons and competition so we have a portfolio of vehicles between DOD and NASA that can be used, not necessarily a joint program but something that will focus on reusability that will ultimately save costs.

Mr. TIAHRT. Do we have the assets necessary now for that type of research? For example, a high speed wind tunnel, is that accessible for the type of research we need to go into the next generation of reusable?

Ms. GARVER. Absolutely. We have the research capabilities. We have the finances if we were to spend less on upgrading expendable launch vehicles.

We are spending much more on the short-term fix at Department of Defense and much less at NASA on the reusable technologies. So, we would recommend continuing to use the shuttle, keep the shuttle flying until we have the reusable replacement but perhaps forego the intermediate upgrades to expendable launch vehicles which is so expensive.

Mr. TIAHRT. Would there be a gap in our current space program if we took money from the short-term fix and put it towards a long-term vision?

Ms. GARVER. No gap at all. The space shuttle people say they can fly—you know, privately they will tell you past 2020.

I believe right now it's just on the books until 2012. But, there is no reason that the reusable technology, even if it's two-stage reusable, cannot come on line well before that.

Mr. TIAHRT. So, you think if we devoted the right resources and channel it towards the next generation of reusable that we could achieve those goals and still fall in line, no gaps in our space program, for the next 30 years, then?

Ms. GARVER. Absolutely. And, more importantly, we could save huge amounts of money.

The most expensive part of our space program is space transportation, access to space. We don't have the money to do all the things we want to do in space because of our limited arsenal of transportation vehicles and because of the cost.

Mr. TIAHRT. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. Thank you very much. I would like to thank all of the members of the panel for coming here today and sharing their views with us.

Again, as I said with the previous panel, members who were not here will have the opportunity to submit questions in writing for each of the witnesses within one week. If they do so, we would like to ask a response within the next week or 10 days after receipt so that we can get the hearing record complete and off to the government printing office for printing.

So, again, thank you for coming.

And, now we will go to Panel Number 3. Panel Number 3 will be on the topic of reusable launch vehicles.

The witnesses are: Mr. Robert Minor, President of the Space Systems Division of Rockwell International in Canoga Park, California; Dr. Jerry Pournelle, the Citizen's Advisory Council on National Space Policy of Studio City, California; and, Mr. Bob Citron, President of the Kistler Aerospace Corporation of Edmonds, Washington.

And, once everyone is seated, the first witness will be Bob Minor from Rockwell International in Canoga Park, California. Mr. Minor

STATEMENT OF ROBERT G. MINOR, PRESIDENT, SPACE SYSTEMS DIVISION, ROCKWELL INTERNATIONAL CORPORATION, CANOGA PARK, CALIFORNIA.

Mr. MINOR. Yes, sir. Good morning. Mr. Chairman and members of the Subcommittee, on behalf of the X-34 team of Orbital Sciences Corporation, OSC, and Rockwell, let me express my appreciation for the opportunity to appear before you today.

I regret that due to a launch in California, my OSC counterpart, David Thompson, cannot be with me. David and I are both eager to explain why we are investing 100 million dollars in a program to develop a new launch system.

The subject of reusable launch vehicles is particularly timely with the selection last week by NASA of four companies to pursue the X-33 and X-34 programs. Timely also is that NASA and its contractors are at a critical crossroads as each tries to redefine itself to meet the challenges of the next century.

As NASA undertakes a reinvention under the leadership of Dan Goldin so, too, is the aerospace industry reinventing itself to reflect the new ways of doing business in a highly competitive global marketplace. The X-33 and X-34 programs are illustrative of the new ways of doing business that will be critical to our success.

The fast track procurement process used on both programs indicates that both NASA and industry are capable of beneficial change. The two month elapsed time from issuance of the cooperative agreement notices to the announcements made last week by NASA is witness to the fact that things can, indeed, be done faster, better and cheaper.

Further evidence can be found in the industry teams assembled to work on X-33 and X-34. The level of interest and willingness to invest demonstrate the private sector's recognition that the nation needs and deserves the best of all worlds in terms of both technological and financial options if we are to remain relevant and competitive.

As members of the Subcommittee are aware, the ultimate goal of NASA's RLV program is to reduce the cost of going to space. Doing so is more than a technological challenge. It is an economic imperative.

During a time when everyone is advocating a "best in world" approach to everything from sneaker manufacturing to parcel delivery, it is clear that the United States cannot afford to watch while others gain routine and cost effective access to space.

While Orbital and Rockwell are excited to be part of both the X-33 and the X-34 programs, I would like to focus on our X-34 approach, which we believe is a good example of this new way of doing business. Three major aspects of the X-34 program warrant mention.

First is the industry/government partnership. Orbital and Rockwell together plan to invest 100 million dollars in X-34 while NASA will contribute 70 million in additional funds to develop and test technologies.

Secondly is the market potential. The X-34 will be designed to dramatically reduce the cost of space transportation. Indeed, our goal is to design and operate a system that will reduce launch costs by a factor of three.

Third is the synergy with the X-33 program. The X-34 will serve as a technology test bed for the X-33 program in terms of certain critical path technologies such as thermal protection systems and advanced composites while at the same time demonstrating new and economic operational processes.

The current X-34 schedule calls for a suborbital flight in late 1997 with the first orbital launch in 1998. To address this aggressive plan, the Orbital/Rockwell technical approach features an air-launched, mostly reusable two-stage system consisting of a fully reusable, liquid fuel booster and a low cost, expendable orbital vehicle.

After separation from a carrier aircraft, the unmanned booster ascends to about 60 miles altitude and deploys the orbital vehicle and an attached satellite. While the orbital stage propels the satellite to its final orbit, the booster reenters the atmosphere and lands horizontally on a conventional runway. Using aircraft-like operational methods, the X-34 booster is then refurbished and prepared for another flight within two weeks time.

OSC and Rockwell are familiar with virtually all commercial and government small launch vehicle customers worldwide and also have extensive experience as spacecraft builders. We have undertaken a careful analysis of the small payload market in the 500 to three thousand pound to lower earth orbit payload classes.

Our analysis shows that approximately 32 percent or an average of about 30 to 34 launches per year fall into these payload classes. Worldwide demand for 500 to a thousand pound launches dominate the small market today and for the next five years.

In the two thousand to three thousand pound category, we have received strong customer indications that the availability of an X-34 system with sufficient delivery capability and significantly reduced cost would stimulate a transition of significant numbers of such satellites to dedicated launches on X-34 operational vehicles.

In addition to Orbital and Rockwell, the X-34 team will utilize five NASA centers around the country—Marshall Space Flight Center, Ames Research Center, Langley Research Center, Dryden Flight Research Facility and Johnson Space Center.

This unique industry-led, government-assisted partnership will demonstrate a new working relationship between the private sector and government, and will serve as a business pathfinder for other NASA initiatives like the X-33. In so doing, it will also promote the continued commercialization of the nation's space launch industry.

In summary, affordable space access is an essential ingredient to economic success in the 21st century. To address the international competition in the global marketplace, the United States must pursue this next generation of launch vehicles.

The X-33 and X-34 programs present a new way of doing business which will leverage the best that both the private sector and government have to offer. The X-34 program has the industry focus and commitment necessary to be a success and will serve as a stepping stone for the X-33 program.

Both programs need and deserve the support of the Subcommittee and the Congress.

[The prepared statement of Robert G. Minor follows.]

Testimony of

Robert G. Minor

President, Space Systems Division
Rockwell International Corporation

before the

Subcommittee on Space and Aeronautics
Committee on Science
United States House of Representatives

Thursday, March 16, 1995

Mr. Chairman, Members of the Subcommittee:

On behalf of the X-34 Team of Orbital Sciences Corporation (OSC) and Rockwell, let me express my appreciation for the opportunity to appear before you today. I regret that due to a launch in California my OSC counterpart David Thompson cannot be with me. David and I are both eager to explain why we are investing $100 million in a program to develop a new launch system.

The subject of Reusable Launch Vehicles is particularly timely with the selection last week by NASA of four companies to pursue the X-33 and X-34 programs. Timely also in that NASA and its contractors are at a critical crossroads as each tries to redefine itself to meet the challenges of the next century. As NASA undertakes a reinvention under the leadership of Dan Goldin, so too is the aerospace industry reinventing itself to reflect the new way of doing business in a highly competitive global marketplace.

The X-33 and X-34 programs are illustrative of the new way of doing business that will be critical to our success. The "fast track" procurement process used on both programs indicates that both NASA and industry are capable of beneficial change. The two month elapsed time from issuance of the Cooperative Agreement Notices to the announcements made last week by NASA, is witness to the fact that things can indeed be done "faster, better and cheaper."

Further evidence can be found in the industry teams assembled to work on X-33 and X-34. The level of interest and willingness to invest demonstrate the private sector's recognition that the nation needs and deserves "the best of all worlds" in terms of both technological and financial options if we are to remain relevant and competitive.

As the Members of the Subcommittee are aware, the ultimate goal of NASA's RLV program is to reduce the cost of going to space. Doing so is more than a technological challenge, it is an economic imperative. During a time when everyone is advocating a "best in world" approach to everything from sneaker manufacturing to parcel delivery it is clear that the United States cannot afford to watch while others gain routine and cost effective access to space.

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United States must pursue this next generation of launch vehicles. The X-33 and X-34 programs represent a new way of doing business which will leverage the best that both the private sector and government have to offer. The X-34 program has the industry focus and commitment necessary to be a success and will serve as a stepping stone for the X-33 program. Both programs need and deserve the support of the Subcommittee and the Congress.

Mr. SENSENBRENNER. Time of the gentleman has expired.

Dr. Pournelle, Citizens Advisory Council on National Space Policy, Studio City, California.

STATEMENT OF JERRY POURNELLE, CITIZEN ADVISORY COUNCIL ON NATIONAL SPACE POLICY, STUDIO CITY, CALIFORNIA.

Mr. POURNELLE. Thank you, Mr. Chairman. To start off with, why are we taking people's tax money and putting it into a government agency? And, you had better come up with some reason why some guy is sending his kid to a city college so that a GS-15 can send his to Yale, it seems to me.

And, if there is a purpose to NASA now that the 70 year war, which we sometimes call the Cold War, is over, it has got to be to look past the profit window into a more long-term research and development regime, because the discounted value of a dollar in 15 to 20 years is, what, about zero? What will you give me if I promise to give you a thousand dollars in 15 years, assuming you are still alive?

Mr. SENSENBRENNER. I will give you a dollar bill with the letter "G" on it just like the Post Office is passing out those stamps.

[Laughter.]

Mr. POURNELLE. Precisely, which means that if there is a purpose to—somebody has got to look 15 years ahead. And, Bell Labs doesn't do it anymore.

And, that kind of leaves the government to look out for our grandchildren. If you think of it in those terms, then the purpose of NASA is to change things fundamentally by looking past the profit window.

And, the one thing that makes a difference in space is access. It's pure and simple.

You've got to be able to get there. And, particularly, you've got to be able to get there with normal people and not just somebody who has got a Ph.D. from MIT.

Now, how do you do that? Well, the usual way you think of to get to orbit, the way Buck Rogers did it, you fly a ship up there and you do something and you bring it back and you fill it up with fuel again and you fly it again.

We don't do that. And, the reason we don't do that is covered in a paper that I wrote called "The SSX Concept" that I think is available here.

And, I won't go into it except that it's purely a function of what we used to think we knew how to do. But, in that, we've got a mind-set towards the notion that payload is important and structure is bad.

And, we've designed all our ships that way. And, I want you to think about it in the other direction.

Airlines typically fly for between three to five times fuel costs. Now, rocket engines are about as efficient as jet engines. They don't have the ISP but they have the heat efficiency.

It takes about the same fuel to fly a pound from Los Angeles to Sydney, Australia as it does to put that pound in orbit. That being the case, why does it cost a thousand times and more to fly to Sydney as it does to fly to orbit?

And, part of that is because if you fly to Sydney, when they land the plane they don't then get passengers off of it and push it off into the sea and start over again. So, what we need to do is to develop ships that fly to orbit and come back and land and get refueled.

And, now we think we know how to do that. And, when the Vice President asked General Graham and me why we didn't do it before back in 1989, when we went and talked him into building the X-1 and started this single stage orbit program, I told Mr. Quayle—actually, Max Hunter told Mr. Quayle, "The reason we didn't do it is because we were too damn stupid to figure it out earlier."

It isn't that there is all this brilliant new technology. We just didn't think about it right.

There are unknowns. We don't yet really know how to build an operational, single-stage to orbit vehicle.

But, the way to do that is to build a couple of X planes, fly some things, because all of your payload weight in a single-stage to orbit ship is calculated in the third decimal place. And, we just don't have third decimal place accuracy data.

That is, if I start with a ship that weighs a half million pounds on the runway before it flies, whether it goes off vertically or horizontally—I favor vertical, but leave that—it starts with a half million pounds. About 450 thousand pounds of that's going to be fuel and oxidant.

And, of the remaining 50 thousand, something between 20 thousand and none is going to be what we think of as useful cargo. The rest of it is going to be the structure of the ship, its tanks and the fuel it takes to get it back home again.

We don't know what that number is between zero and 20 thousand. We are pretty sure it's probably between nine thousand and 20 thousand.

But, we don't know. And, the reason we don't know is because we are dealing with the third decimal place function here. And, we just don't have the data.

So, what you need to do is fly some rocketships. You need to upgrade the DCA, which should have been a full stage ship to begin with. And, you need to build something like what I've called an SSX, which is an experimental ship.

And, it don't take any 10 years. We went from the drawing board to killing Germans with a P-51 in something like 100 days.

You don't have to take five years and billions and billions of dollars. It's just that everybody has got accustomed to doing it that way.

And, they like to take the money and sit around and think—and have eight million people sit around and think about what could go wrong. And, when that happens, you don't get real X programs.

And, I put it to you that we need to go back to the same kind of concept that solved the problem of supersonic flight. Now, what was the payload of the X-1? Well, it was Major Yeager and a stick of Beeman's gum.

And, that's what we need to do now is build ourselves a ship that flies to orbit and comes back. It will cost about a billion dollars.

About four years is all the time it will take. If you can't do it in four years, you shouldn't do it at all.

And, when we are done with it, we will know how to build the operational ship that these chaps want to do. And, that's basically what I have to say this morning.

[The prepared statement of Dr. Pournelle follows:]

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The SSX Concept

Jerry E. Pournelle

A Bit of Background

The intuitively obvious way to get to orbit is to build a rocket ship that will go there, fly around in space, and return to Earth for refueling and reuse. It's what Buck Rogers did. This is so obviously the *right way* that people have to be taught why we don't do it.

Explaining why we have not yet built that kind of ship, and why we can and ought to build one now, is going to take a little work. Fortunately the math is simple: there's only one actual equation in this paper. It's presented in a couple of forms, but it's still only one equation, and it's a pretty simple one. It's called the classical rocket equation, and studying it can teach us a lot about what has happened to the space program.

You don't have to be a rocket scientist to follow the argument.

The classical rocket equation:

$$M_0/M_1 = e^{(v/c)} \qquad (1)$$

Where M_0 is the initial mass of the rocket; M_1 is the mass of the rocket at velocity v; c is the exhaust velocity, which is to say, the speed with which the propellant is ejected out the back end of the rocket in a direction opposite the line of flight; and e is the constant 2.71828 — usually rounded to 2.7183.

The quantity M_0/M_1 is called the mass ratio, and is critical to the concept of working rockets.

In the above, we have assumed that the rocket started with an initial velocity of 0, and that it traveled through empty space

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unaffected by gravity. That formula can also be used to find a change in velocity of a rocket in empty space: substitute for v the quantity delta-v (or change in v, often written as delta-vee), where M_0 is the mass at the initial velocity and M_1 the mass at the final velocity.

That equation is often written as

$$\text{(2)} \qquad \text{Delta-v} = (V_e)*\ln(M_0/M_1)$$

where V_e is the exhaust velocity; why the conventional representation changes from ‘c’ to V_e is historical and utterly unimportant, and if you write that as

$$\text{(3)} \qquad v = c \times \ln(M_0/M_1)$$

you'll see that it's really formula (1) rewritten. It used to be that you had to look up the natural logarithm (the log to the base e) of the mass ratio in a book of tables, but nowadays an inexpensive calculator gives it to you at the punch of a key.

A rocket taking off from Earth would experience both atmospheric resistance and gravitational attraction. That doesn't change the fundamental usefulness of the rocket equation, but it does complicate calculating the result. You may think of atmospheric resistance and gravity as “consumers” of velocity: that is, the final velocity of a real rocket will be lower than that calculated by the rocket equation.

Gravity consumes velocity. How much is a function of flight time. For a first approximation this will be about 2500 feet per second. In practice, to design for the delta-vee required to get into orbit (about five miles per second, or 25,000 feet per second), add an allowance for loss of delta-vee due to gravity. If you can achieve that despite the atmospheric resistance, you've got your ship.

Atmospheric resistance harms us in two ways: not only does it provide physical resistance to the rocket's movement through the air (drag), it also hinders the escape of the propellant out the back end: which is to say it slows that down, or lowers the “c” in the equation.

It's A Drag

The faster the rocket goes the worse the drag. On the other hand, if you're headed for orbit, the faster the rocket, the less time spent in the atmosphere. Drag is a complex function of the size, shape, presented surface area, atmospheric density and temperature, winds, and flight profile. Artillery officers are well acquainted with this, since the effects can be quite significant on the trajectory of a round traveling five miles or more.

Drag has the effect of consuming about 1500 to 2000 feet per second of the rocket's velocity.

The result of all this is that a first cut analysis shows that to achieve orbit, a rocket needs about 30,000 feet per second total velocity. It won't ever go that fast, because gravity and drag will have consumed some 5,000 feet per second, but your engines have to add that much energy to the vehicle.

Approximate Required Velocity To Orbit

Orbital Velocity	25,000 feet/second
Allowance for drag	2,000
Allowance for gravitational pull	2,500
Safety Margin	500
Total	30,000 feet/second

You can find out a lot just by playing with the rocket equation. I did, in high school, after discovering this and much more in Willy Ley's classic *Rockets and Space Travel*. (Willy's book kept appearing in revised editions over the years: I think the last one was *Rockets, Missiles, Space Travel, and Man in Space*. It's still one of the best introductory works ever done.)

For one thing, if you want a final velocity of twice your exhaust velocity, you need a mass ratio of e^2, and your calculator (or slide rule when I was in high school; I sure wish I'd had a TI-30) shows that's 7.4.

Well. The orbital velocity of the Earth is about 25,000 feet per second (fps) even without allowances for drag and gravitational pull while you're going up. The best exhaust velocity you'll get from ordinary chemical fuels is around 7,000 fps. Even at three times the exhaust velocity, we see from our equations that the mass ratio is e^3, or just over 20. Mass ratios of 20 and more weren't considered possible in those days. They're nothing like easy now with the best and most modern materials. Thus, even without allowance for gravity and drag losses, we can see that getting to orbit isn't easy.

Heavy Stuff

We've seen that the mass ratio is the mass at takeoff divided by the mass at velocity. The mass at velocity — in our case what gets to orbit — is conventionally divided into two components: structure and payload. Payload is the stuff you wanted to get into orbit. Structure is everything else: fuel and oxygen tanks, shrouds, casings, rocket engines, pipes, etc. Note that the more structure, the lower the mass ratio. Since a high mass ratio is Good, there came about a mind set among rocketeers: Structure is Bad.

Note also that to get high mass ratios you need *big* rocket ships. That follows because there are minimum weights to many rocket parts. This is known as "minimum gauge," meaning that you can't make it any thinner or lighter. Combustion chambers have to be rugged. Pipes must be thick enough to hold pressures that don't get smaller just because you're trying to make a smaller rocket. Thus the easy way to build a single-stage-to-orbit rocket ship would be to make it *big*. This is the approach taken by Captain Truax with his Sea Dragon. Unfortunately, size costs. To make a larger ship get off the ground you have to add more engines, or make the ones you have more powerful. Either way is costly. There's also ground handling: clearly it's easier to move, store, and service a smaller ship than a larger one. Truax's Sea Dragon would be built in a shipyard, and towed out to sea to be launched from water. (See JPAS Vol II., No. 1, ppg. 1 - 18.)

Big also means inflexible. All your payload will go to the same orbit. There's merit to that, but there's more merit to a capability for putting smaller payloads into a number of different orbits, at least until the market expands to demand the heavier lift.

Back in the days when people first thought a lot about rocket ships, fuels with real exhaust velocities of 7,000 fps weren't all that easy to come by, neither were rocket engines capable of handling the corresponding temperatures, so speculation about SSTO was pretty theoretical. At the top of page 165 are some possibilities we can consider (again from Willy's book).

Those were with practical engines running at 300 pounds per

Propellant	Combustion Temperature(°F)	Exhaust Velocity @ Sea Level (feet per second)	Average
Nitromethane	3950	6150	7420
Nitric acid/analine	5070	6200	7300
Peroxide/methyl alcohol	4160	6300	7420
LOX/ethyl alcohol	5260	6870	8090
LOX/hydrogen	4390	10150	12000

square inch, which was state of the art then. The "average" value is a bit lower than the actual vacuum exhaust velocity. These are the kinds of numbers people thought about in 1940 - 1950.

Getting There From Here

So. How were we to get to orbit?

Some simply assumed we'd never do it. Vannevar Bush, Chairman of NASA's predecessor NACA and dean of U.S. science during World War II and just after, told the Congress of the United States that there was simply no possibility of intercontinental ballistic missiles (ICBMs). "You can leave that out of your thinking. I wish the American people would leave that out of their thinking," he testified to the House Military Committee in 1946. You couldn't build ICBMs and you certainly couldn't build Moon rockets and launch satellites.

Dr. Bush had great prestige, and his convictions led to great difficulties for the rocket program; but even as he was saying this, others knew better.

Equation (1) condemns us to remain on the Earth's surface unless we can either get very high exhaust velocities, or absurd mass ratios.

The American Rocket Society chose the second way.

Rockets consist of structure, tankage, guidance mechanisms; all kinds of stuff besides the "payload" you want to get into orbit. Suppose you could throw that junk away when it wasn't needed any more, if you could fling the tanks overboard when they were empty? Then you wouldn't have to push that dead weight along.

That, of course, is precisely what a multi-stage rocket does. Incidentally, early books on rocketry generally contain no index reference to "stages" or "staging." They spoke of "step rockets." (See Table 3.)

A typical two step rocket, as described in Willy's book:

Payload of second step	20 lbs
Structure of second step	180
Together	200
Fuel, second step	400
Total of second step	600
Payload of first step (total second step) then is	600
Structure of first step	4400
Together	5000
Fuel for first step	10000
Takeoff weight	15000

Table 3

The takeoff weight is today generally called Gross Liftoff Weight, or GLOW. What's given here is about the size of a Viking sounding rocket.

What's the mass ratio here? Note that the second step starts at 600 and ends at 200 pounds, for a mass ratio of three. The first step starts at 15000 and ends with 5000, so it's also a mass ratio of three. However, for purposes of calculating the mass ratio of the total system, we can *multiply* the two stage ratios, to get a final mass ratio of nine; meaning that this rocket should get a final velocity of something over two times the fuel exhaust velocity; so that if it burned, say, ethyl alcohol and liquid oxygen, which has a sea level exhaust velocity of about 1 1/4 miles per second, we ought to get about 2 1/2 miles per second or 12,000 feet per second. In the real world, the first stage is unlikely to reach 6000 fps because of atmospheric drag and gravity, but the second should get most of the theoretical delta-vee.

The ultimate staged system was Saturn/Apollo, which at liftoff stood 363 feet tall, with GLOW of 6,423,000 pounds. The first two stages dropped away to put about 110,000 pounds into orbit prepatory to heading for the Moon — corresponding to an effective mass ratio of well over 50 had it been a single stage system.

Staging, in other words, can give quite high mass ratios; and that, of course, is how we got to space, to orbit and to the Moon. We built disintegrating totem poles, throwing away most of the rocket to get velocity. It wasn't an elegant solution to the problem but it did the job.

However, it got us used to thinking of rockets as ammunition, rather than as airplanes. A lot of people never got over that. It also got us to thinking that the ship itself was useless junk: the only important thing was the "payload" and the sooner you could get rid of everything that wasn't payload, the better off you'd be. That attitude is also still with us.

The absurdity of the disintegrating totem pole was pretty apparent, though, so some continued to work on single-stage rockets. Since mass ratios of 20 looked fairly silly (and required enormous ships), they had to look at higher fuel exhaust velocities.

In Willy's engine, hydrogen and oxygen at sea level have an exhaust velocity of 10,150 feet per second: 25,000 fps divided by that is 2.46, and e to the 2.46 is 11.7. While that's a pretty severe mass ratio, it's not utterly absurd. Moreover, as soon as you get above the atmosphere, hydrogen and oxygen give exhaust velocities in the order of 12,000 fps, and that corresponds to mass ratios less than ten; and *that* is at the edge of what we knew how to do.

SSTO Concepts Continue

Even in Willy Ley's day many rocketeers said "just wait until we have hydrogen engines." Willy was skeptical. Hydrogen was tough stuff to handle. It didn't burn properly in the engines they could build, it needs insulation to keep it cold, and it's not very dense, so the tanks have to be big. That means a lot of heavy "structure" which by definition is dead weight. Hydrogen engines would be nice to have, but they would also have their problems.

The result was that most rocket engineers followed the staging path, which was, after all, the only path to go down if we wanted to accomplish anything in the 50s and 60s; but a few kept looking at Single-Stage-to-Orbit or SSTO. Among them were Phil Bono, Robert Salkeld and Gerry Driggers. Driggers was a professional engineer, and at one time the President of the L5 Society. Salkeld was an associate of Dr. Muller. They, and others, were able to keep the notion of SSTO alive, but by 1980 it was just barely alive.

NASA's Space Shuttle, meanwhile, was originally conceived as a two-step rocket with both steps recoverable. One Boeing design called for both steps to be liquid rockets, and both would be manned. The first step flew to the edges of the atmosphere — say 80,000 feet — then separated and returned to Earth. The second step flew on to orbit. In at least one design concept, only the first step had wings. The second was a lifting-body design.

There were other Shuttle concepts, but all involved recoverable systems. The notion was to fly to space, do something, return to Earth, refuel and fly again. Some single-step Shuttle systems were examined, but the initial costs were thought to be very high for a winged vehicle — radically new engines would be needed — and most Shuttle concepts were for a two-step system.

Then something horrible happened. Precisely what isn't important; but Shuttle changed from a reasonably elegant reusable system to the Monster That Devoured The Budget.

Partly this was caused by engineering competition: Shuttle engines were designed to high performance, to run at high temperatures at very high pressures: something more appropriate to the ammunition concept than reusability. Things were stretched out, to keep initial costs low, even if that made the final price tag higher. Thus, far from a low cost per launch system, Shuttle real costs per launch grew to a billion dollars each. The official cost is over $500 million per launch.

In 1979 it wasn't entirely clear that Shuttle would become a monster. Some people had suspicions, but after all, Shuttle was the only game in town; so the space community was asked to swallow its doubts and support NASA to get Shuttle flying, warts and all. Have faith, we were told; and we had faith. Hundreds of Shuttle launches were planned. NASA sold people on the notion of "Getaway Specials," low-cost experiments that anyone, even high schools, could do in space. Shuttle was going to make American a spacefaring nation.

That didn't happen. The number of Shuttle flights scheduled was scaled down, then down again. Precisely what happened to Shuttle isn't relevant to this paper, so I'll pass over it, except to note that Shuttle was designed in a way that requires thousands of experienced people to keep it flying. You cannot operate Shuttle without a big standing army of technically trained people. It also requires critical ground handling facilities: now that the Vandenberg effort has been abandoned there's only one place in the world that you can launch a Shuttle from.

For all that, we all cheered when *Columbia* flew, and we hoped for great things. However, as early as 1980 some people said that Shuttle wasn't going to be what we wanted it to be. One group, led by Carl Sagan and Bruce Murray, said that Shuttle would eat the space sciences budget. Unfortunately, their valid critiques of NASA's Shuttle were lost because of their vehement attacks on the whole concept of man in space. As Larry Niven once pointed out, every time Sagan convinced someone there was no need for man in space, he probably lost a supporter for space. Few Americans wanted to spend money to make the universe safe for robots. They wanted to see heroes go to space and return to ticker tape parades.

To many of the rocket scientists, though, those astronauts were merely "structure," junk that worsened the mass ratio. We didn't need man in space, though Skylab demonstrated that people could be useful after all, but Skylab was an odd mission, not part of the "main stream" effort, as demonstrated when NASA took a fully operational Skylab and the Saturn rocket that could have launched it, and made them into museum displays.

Shuttle, dubbed the Space Transportation System, meant that all other systems for putting stuff into orbit were abandoned. The last fully working Saturn rockets, each capable of putting into orbit about five times a typical Shuttle payload, were destroyed.

Not everyone agreed that Shuttle was the optimum way to go. One lonely voice was Gary Hudson, who was not part of the "men aren't needed in space" movement.

A Diversion for Definitions

> A moment off here for reminding readers what terms mean. SSTO is "Single-Stage-to-Orbit." LOX is liquid oxygen, which is a cryogenic fuel. "**Cryogenic**" means that it must be kept at very low temperatures. LOX is cold stuff, but it's a lot warmer than liquid hydrogen. The RL-10 is a Pratt and Whitney "expander cycle" engine that burns LOX and liquid hydrogen. It was designed for an upper stage, and was employed in the Atlas/Centaur rockets which so greatly aided space science in the early days.
>
> "**Storable**" fuels are those which can be kept at "room" temperatures. Rockets carry both fuel and the stuff to burn the fuel in (generally something that supplies oxygen if not oxygen itself). It's a lot easier to have storable fuels than storable oxidants. Storable fuels can be relatively nice stuff like propane and kerosenes — the various JP and RP fuels, such as RP-5 (Rocket Propellant 5) are kerosene like. Storable oxidants tend to be nastier stuff, like red fuming nitric acid.

> Hydrazine is a pretty nasty storable fuel; both those latter were used in early air defense missiles.
>
> GLOW means "Gross Liftoff Weight," i.e., the weight of the fueled ship as it takes off. Dry weight means the empty weight of the ship before you fuel it. Payload can have several meanings, but usually refers to what you wanted to put into orbit other than the ship; for a reusable SSTO the traditional division of the ship into "structure" and "payload" may not make a lot of sense.
>
> Council means the Citizens Advisory Council on National Space Policy, a group that meets periodically to give advice to national authority on space matters.

SSTO Reappears

In 1980 Hudson presented to the first meeting of the Citizens Advisory Council on National Space Policy a briefing on the Phoenix concept. Phoenix was a fully reusable single-stage-to-orbit LOX hydrogen ship which he had brought to preliminary design description stage.

The Phoenix concept presented to the Council was a 450,000 pound GLOW reusable vehicle designed to orbit a 5-10 ton payload manned or unmanned. The powerplant would have been either an aerospike — see below — or multiple bell nozzle engines. It was to be fabricated from the technology of the day, principally aluminum and composites, and featured active water cooling to handle the heat generated during re-entry. This cooling system, which Boeing called a water wall, was studied in the early 1960s as part of the Boeing Dyna-Soar proposal.

Hudson's proposal was politely heard at the 1980 meeting, but the idea of SSTO was dismissed without much discussion. In retrospect that was an error, and as Chairman I take responsibility for it. No one at the meeting — which included Salkeld, known to be enthusiastic for SSTO — spoke up in favor of a full debate, and thus SSTO was quietly dropped in favor of space plans involving Shuttle missions. In those days we thought there would *be* Shuttle missions. We knew those missions would not be cheap: but we never dreamed that they'd go to $1 billion a mission. And Hans Mark, incoming Deputy Director of NASA, had personally asked us for support for the Shuttle program.

We wanted to believe. We were still being asked to have faith, and many of us swallowed our doubts to present a common front in favor of "the space program"; and "the space program" in those days meant Shuttle.

By 1986 it was clear that the U.S. space program was in trouble. People spent their entire professional lives anticipating planetary and space science data from space missions that were long delayed or canceled outright. Even our weather satellite observations were in danger of severe degradation or being lost altogether. The only commercial exploitations of space were communications and some commercialization of ground observation data: and both of those programs were badly underfunded.

It was obvious that if space activity were to grow, it would need more commercial support: space should be a source of money, not a sink for government funding.

In 1986 the Council wrote reports that strongly recommended new launch systems. "If you want to be a spacefaring nation you must: Build more rocket ships. Fly more rocket ships." We had not as yet fastened on any particular system; there was still hope that a variety of programs might be funded.

By 1987 it was clear that there would not be a variety of programs, and Shuttle was not taking up the slack. By then the French getting far more commercial space business than the U.S. Even Red China got in the act. In fine irony, a Chinese refrigerator company launched the two commercial satellites the Shuttle recovered and brought down for repair.

The Council met to consider particular systems. We were prepared for extensive debates. During the years 1980-1989 there had been considerable interest in the National Aerospace Plane, NASP, sometimes known as the "Orient Express." This was a winged hypersonic ship that employed air scoops: oxygen would be drawn from the atmosphere, saving the weight of tankage (lowering the liftoff weight), and thus presumably improving the mass ratio.

When Hudson again brought up the Phoenix concept in the Fall 1983 Council Meeting, the chief opposition was from advocates of winged vehicles. Winged vehicles seemed very logical to many. After all, if you're going to operate like an airline, it's reasonable that the ships look and act like airplanes. The result was that the Council endorsed NASP research, and said nothing about a wingless SSTO.

By 1988 most of the Council members had lost their enthusiasm for winged vehicles. In particular, Max Hunter had become a convert to wingless multi-engine SSTO ships, and had developed a number of SSTO concepts while at Lockheed. Astonishingly, in the

1988 meeting held to choose a specific line of space ship development, there were almost no debates. Just about everyone present recommended a Single-Stage-to-Orbit Vertical Takeoff/Vertical Landing fully reusable multi-engine system. From having no adherents other than Gary Hudson in 1980, SSTO had become the unanimous choice of a distinguished group of rocket scientists and engineers.

From Here To There

SSX

The Council recommended a ship called SSX, Space Ship Experimental. It was explicitly intended as part of a revival of the highly successful X-airplane program.

Analysis One

SSX was recommended by two different analyses. The first was an engineering analysis that indicated that it could be done, probably with existing engines. There was no agreement on how much payload SSX might carry. Gordon Woodcock was concerned about payload: the ship might not have any at all. His final calculations showed a probable payload of 5,000 pounds using existing engines; but while that sounds like a comfortable number, when we are dealing with mass fractions around 10 — which we must in a single-stage design — then it doesn't take much change in engine performance or tankage weight to wipe out all the payload.

SSX was to be a "hydrogen rocket" as Willy Ley would have called it. In 1947 the hydrogen engine was an exotic concept. By 1989 the Pratt and Whitney RL-10 hydrogen engine had been tested thousands of times without failures. There had been other changes.

The RL-10 had been flown often enough to give hard performance data.

Performance of the RL-10

	Sea Level	Vacuum
Exhaust Velocity	10,615	14,478
I_{sp}	330	450

Table 4

(I_{sp}, or specific impulse, is now usually used instead of exhaust velocity. It is nothing more than the exhaust velocity divided by gravity, or 32.17 feet per second per second. The main reason I_{sp} is generally used now is that it's a smaller number, but it is sometimes described as an index of efficiency: it is the pounds of thrust per pound of fuel per second of acceleration.)

Assuming we need 30,000 feet per second, at an exhaust velocity of 10,615 (I_{sp} of 330) we need a mass ratio of 16.88, which is beyond achievement; but at 14,478 ($I_{sp} = 450$) it's only 7.6. Since the rocket spends more time in vacuum, the average exhaust velocity during the flight is going to be higher than 10,615; precisely what it will be can be calculated, but the calculations are sensitive to the flight path, and that's sensitive to the structural weight; meaning there's enough room for experts to disagree. However, the numbers are intriguing, and recall, these are figures for well-tested, reliable, existing engines.

After three days of intensive meetings, we concluded that the SSX could be built, for under a billion dollars, and in under four years time. This was an engineering, not a political, analysis: one rule of the Council is that we will not paralyze ourselves with political pessimism. If a concept is technically feasible, we will recommend it and hope that it will find a political — or commercial — champion. We saw no technical reasons why SSX could not be constructed using existing technologies and generally employing modifications of existing equipment.

A second meeting, held in Fall 1988, confirmed this conclusion.

Analysis Two

The other line of argument for SSX was more theoretical.

Start with this: Most people in the space community still think of ships as ammunition rather than aircraft. What happens if you think of them as aircraft?

Airlines typically operate at a small multiple of fuel costs. It takes roughly the same fuel to fly a pound to Australia as it does to put that pound in orbit. Granted that liquid hydrogen will be rarer and more expensive than jet fuel, the actual costs of space flight with Shuttle are not several times fuel costs but several hundred times those costs. Rockets are not less efficient than jet engines. Why, then, should space flight cost so much?

The answer wasn't hard to find. First, the cost of a ticket to Sydney would be a very great deal more than a few times fuel costs if they had to throw away the airplane after you took a trip in it. Clearly expendables — ammunition — could never be as cheap as airline style operations. You have to reuse the ship.

That line of thinking had led to Shuttle, and it certainly wasn't cheap. What went wrong there? That answer wasn't hard to find either. Typical airlines have 120 employees per airplane, and most of those sell tickets. The highly technical SR-71 program had about 48 employees per airplane, many of them data analysts. By contrast, Shuttle has 20,000 people to operate four vehicles. The typical annual cost of a technical employee today (including benefits, retirement, office facilities, etc.) is over $125,000 a year, meaning that a standing army of 20,000 costs at least $2.5 billion a year before they launch anything at all.

Clearly Shuttle was not designed for operational simplicity. That provided the primary design directive for SSX: its design would be driven by operations considerations, not by performance. Performance has to be "Good Enough." It doesn't have to be a lot better. Better is the enemy of good enough. The important thing for SSX is simplicity of operations, low costs and low personnel requirements.

Another SSX design criterion was *savability*. It ought to be able to tolerate losing an engine on takeoff: to hover, burn off fuel, and land. This clearly desirable feature has a vast influence on total space operations costs.

There are other benefits, but surely it is established that if you can build this kind of rocket ship, you would want to have one.

Size

Gary Hudson's original Phoenix was a bit smaller than the SSX we envision.

We thought in terms of a ship with about 45,000 pounds of structure, and 5,000 pounds of payload. With a mass ratio of 10 this produces a GLOW of 500,000 and requires an average exhaust velocity of 13,029 feet per second. This is just within the capability of existing engines, and the structure weights are thought to be achievable.

Clearly none of these round numbers is sacred. The truth is, until we begin to build that ship, we won't know precisely what those numbers are: and that's the rub, because if we size the ship small to keep the total costs down, we run the risk of not being able to make orbit, or of making orbit with no payload.

Thus some proposals for DC-Y, a possible implementation of the SSX concept, call for a GLOW of 1.4 million pounds. This makes for a large ship, complicating ground handling, and requiring considerable thrust which in turn requires engine developments. That large a ship will have increased costs and complexity of operation, so a smaller ship is preferred. However, the big ship is in a sense a "conservative" design, in that it contains considerable reserves of payload mass that can be sacrificed to compensate for unforeseen problems.

The Council has no unanimous recommendations on sizing; some members defend a wide range of values. It is time to *fly* something; without new flight test data, it is impossible to choose the optimum design size.

We recommended that we build the SSX and get on with the program; at worst we'd learn what we need to know to build the proper size bird.

Design for Test Flights

At the Council meeting that recommended SSX it was unanimously agreed that a ship using RL-10 engines, modified for altitude compensation, would have a marginal orbital capability. It might not be able to make orbit, but it would be close to that capability. That ship could be flown incrementally. That is, it could take off not fully fueled and fly for short distances and times, thus allowing an exact determination of its capabilities. It could then be modified: add thrust, or reduce weight, to "nickel and dime"its way to an orbital capability.

This incremental test philosophy seems to have been misunderstood — in some cases rather deliberately misunderstood.

"Almost make orbit" is of course a pretty dangerous thing to do — if you try to make orbit and fail. However, a ship that can "almost make orbit" can be used for a *lot* of testing in test missions that don't at all try for orbit. At each test stage you gain a new appreciation of the ship's capabilities, and the next test is designed accordingly.

Given the experience of flying a ship that can "almost make orbit" we would fully understand the requirements of a ship that *does* make orbit. This incremental approach to space ship design is similar to the X airplane programs that produced such dramatic results in U.S. aviation.

The original SSX concept envisioned building a couple of ships that would "almost make orbit." With luck and skill, one of them might actually be sent on an orbital mission. It would probably have no payload other than itself, but so what? The payload of the X-1 was Major Yeager. The mission wasn't to deliver payload, but to fly faster than sound. Similarly, the mission of SSX-1 is to develop the means for airline-like space operations, not to deliver payload into space.

SSX-2 would take what was learned from SSX-1 to build a ship that would reliably go to orbit and return. Once again, the amount of payload wasn't critical; but everyone was certain that with engines developed from what was learned by *flying* SSX-1 we would have a payload of at least 9,000 pounds, and with data developed by *flying* that ship, we could improve SSX-2 payload considerably: some expected as much as 19,000 pounds.

Ammunition or Airplane?

Many rocket systems were developed for use as ICBMs. A missile needs performance and one-time reliability. There's no point in building the engine to last. It won't be used but once (and with luck never at all).

The result was that many rocket engineers fell into the habit of thinking of rocket motors as part of an artillery system; they were ammunition, and it was pointless to build them for anything else. Even when the system was to launch a satellite, or a manned spacecraft, it wasn't likely to be used again.

Shuttle was of course different, but except for Shuttle there wasn't much effort put into reusable, restartable rocket engines.

Even so, there was an exception. The Pratt and Whitney RL-10 is ultra-reliable, and test engines have been restarted and refired many times. The P&W RL-10 was developed by engineers exclusively familiar with aircraft engines, not missiles, and many think that was a major influence on the engine design. In any event the RL-10 demonstrates that you can build reliable, reusable rocket engines if that's what you set out to do.

Technical Risks

It was unanimously agreed that the technical risk of the SSX program, through SSX-2 with a payload of at least 10,000 pounds, was a lot lower than the technical risk of Apollo: that is, the SSX program contained far fewer technical unknowns than there were in going to the Moon when Kennedy announced that mission.

Exactly how far single-stage-to-orbit — SSTO — technology could be taken wasn't predictable until we had built and *flown* some of these machines. However, it was clear that any advances in material science — such as were coming out of the NASP program — would instantly benefit the SSX. In general, anything that makes

NASP more feasible helps SSX at least as much.

There were some technical unknowns. One was the engine concept known as "aerospike." This is a method of mounting a number of engines in a pattern that allows their exhaust plumes to compensate automatically for altitude.

Explaining aerospike and altitude compensation requires more technical detail than I want to give in this paper. The important thing to remember is that rockets are more efficient in a vacuum than in an atmosphere (which is why you want to get out of the atmosphere as quickly as possible when you fly rockets). Whatever is done to make the rocket work better in an atmosphere will detract from its performance in vacuum. It can also add weight. The aerospike concept tries to get around some of those limits.

Aerospike engines were built and static tested decades ago. The results were encouraging, but hardly decisive. Some people are convinced they can build a working aerospike design with existing engines, and others are convinced that if you do build it you won't get enough altitude compensation to make it worth the effort. The consensus seems to be that aerospike is the proper way to do altitude compensation, but some doubts remain about the effects of dynamic pressures at certain critical altitudes between 25,000 and 75,000 feet. In that flight regime the effect of dynamic or slipstream pressures could be to lower I_{sp} by as much as 30 seconds, corresponding to a lowering of exhaust velocity by 965 feet per second. However, this applies only in the regime around 50,000 feet, and the rocket doesn't stay there very long; so the total effect on average exhaust velocity (and thus mass ratio, and thus payload) for the flight isn't accurately known. The question won't be resolved without flight testing.

Since aerospike engines have great benefits, it seems reasonable to have a program to develop both aerospike and the proper engines for use with them. It wouldn't cost more than fifty million dollars a year, which is pretty trivial given the potential gain. In particular, SSX/SSTO benefits from the gains our analysis says you'll get with a working aerospike. However, SSTO will work without aerospike, and while the original SSX concept employed aerospike in the proposed design, it was not considered essential to the SSX concept. Altitude compensation can be done with variable geometry rocket bells.

Another technical unknown is re-entry geometry. If there's anything we understand about re-entry, it is blunt cones, so that a nose first re-entry vehicle is easy to conceive. Moreover, nose first gives considerable increases in cross-range maneuver capability for landing. However, since we want to land SSX tail down, and getting a blunt cone from nose first to tail first isn't easy, we either have to learn how to make that rotation or we have to let SSX re-enter tail first.

Tail first entry has many advantages. Among them is the possibility of running the engines at idle, letting the exhaust plume serve as the heat protection mechanism for the ship. Once again, this is not a concept critical to the success of SSX, but it does or could save structural weight. It is also another unknown: we can simulate all we like, but we won't know how well that works until we try it, and right now we aren't trying much of anything.

One bugaboo that isn't as big a problem as it looks is the tail first landing. This looks frightening, since if the fire goes out the ship falls: it can't possibly glide. Here is this enormous thing falling—. However, once the ship has re-entered it is nearly empty. The terminal velocity in atmosphere is something under 100 miles per hour. The empty weight of the ship is less than that of an airplane. No one wants to crash a space ship, but the consequences of crashing an SSX are a lot lower than those of crashing a Shuttle or a 747.

The real debate over single-stage-to-orbit involves materials and structures. Clearly we know how to build the ship. The question is, will the structure — complete with frame, tanks, motors, controls, re-entry shield, landing gear, crew and cargo compartments — be light enough to allow the ship to have a reasonable payload?

Some questions on structure weight were resolved in a series of classified experiments code named HAVE REGION. Recently declassified, these were conducted by the Strategic Defence Initiative Office (now named Ballistic Missile Defense Office). In HAVE REGION, several contractors built scaled versions of sections of a single-stage-to-orbit ship, using rather conservative mixtures of aluminum and composites. The results lead structural experts to conclude that HAVE REGION demonstrated that vehicles having mass ratios and strengths better than those required for single-stage-to-orbit can be constructed. The questions remaining have to do with costs.

Most experts who have studied single-stage-to-orbit technology are agreed that an SSTO ship can be built, and that it will have some payload; and while there is debate over how much payload — estimates range from 5,000 to 19,000 pounds to low Earth orbit

(LEO) — nearly everyone is agreed that a practical, savable and resuable ship with about 9,000 pounds payload can be constructed. The question is, can a ship that lightly built be used enough times to justify its construction?

Note that this question is as much economic as technical.

There are other technical risk factors in SSX design, and they all work the same way: if things turn out well that increases performance, and turning out the other way doesn't. If every one of those factors goes the wrong way, SSX won't have much payload. If every one of them goes *really* the wrong way, it won't have any payload at all. However, there is no reason to suppose that they'll all go wrong. Things don't usually work that way. In fact, the way to bet any one of them is that it will go right: Clarke's Law states that if a venerable scientist tells you that something is possible, he's right, and if he says it's impossible he's most likely wrong. Experience has proven Clarke correct. (Clarke, of course, remembers Vannevar Bush very well.)

The Real Risk

The real risk to SSX was always known to be organizational.

The first risk is capture by a group that wants to study it to death.

There are two major engineering design philosophies. One says, "Do things right. Don't waste money putzing around. Understand what you're doing, figure out in advance all that can go wrong, and then build it right in the first place."

The other says "Do the best you can, learn from that, and then go on from there. You'll learn more from one good flight than from a thousand computer simulations."

Both concepts have merit. The first can be thought of as the "prototype" approach. You don't build anything unless you'd be willing to build a lot of them. The other is the "X vehicle" approach: X ships aren't prototypes. Build two, fly one until you prang it, use what you learned to modify the other one, and fly that until you augur it in or there's nothing more to learn.

We are convinced that SSTO requires the X concept. Alas, there's nothing so magical about SSTO that it is immune to the "let's do it right" approach. Capture by a "do it right" group would certainly delay SSTO well into the next century.

Another danger is the "requirements" group. X concepts are to develop *technologies*, not vehicles; if you start hanging specific requirements on an experimental vehicle, you will end up trying to "do it right"; which is generally fatal to an X program. Single-stage-to-orbit ships will have many customers; but the potential users of SSTO should not dictate the development program.

Conclusion

The conclusion is obvious. SSX is possible. An SSTO ship could be built and flown in fewer than four years and for less than a billion dollars. We believe that doing that will show how to design and build SSTO vehicles with payloads of about 15,000 pounds, operate at costs of four or five times fuel cost, and require about 50 technical persons per vehicle.

Such a ship would be "savable": it could experience an engine out without disaster.

Savability plus low cost to orbit will have an enormous effect on payload design, as well as on commercial uses of space. Payloads need not be overdesigned, since the cost to orbit will not be enormous. Obsolete satellites can be replaced.

Airline style operations to space will lead to space commercial activities on a wide scale; look at what happened to air travel when reliable systems with low operating costs became available.

SSX could lead to the ships that will make America a spacefaring nation as promised by John Kennedy all those years ago. ◇

Appendix: Some Data

The following data on LOX/LH2 engines is taken from Rocketdyne publications.

J-2 230,000 lb Thrust
427 sec I_{sp} (Vac) = 13,715 fps e.v.
Area Ratio 27.5:1
O/F Mixture Ratio 5.5:1
Chamber Pressure 763 psia
Weight 3480 lb

J-2S 265,000 lb Thrust
435 sec I_{sp} (Vac) = 13,970 fps e.v
Area Ratio 40:1
O/F Mixture Ratio 5.5:1
Chamber Pressure 1246 psia
Weight 3800 lb

SSME 513,000 lb Thrust
455 sec I_{sp} (Vac) = 14614 fps e.v
Area Ratio 77.5:1
O/F Mixture Ratio 6.1:1
Chamber Pressure 3240 psia
Weight 6990 lb

Linear 200,000 lb Thrust
455 sec I_{sp} (Vac) = 14614 fps e.v.
Area Ratio 115:1
O/F Mixture Ratio 5.5:1
Chamber Pressure 1224 psia
Weight —

(The Linear aerospike was not built as a flight weight engine, so the engine weight is uncertain.)

RL-10A-3-3A 16,500 lb Thrust
444 sec I_{sp} (Vac)
Area Ratio —
O/F Mixture Ratio 5.0:1
Chamber Pressure —
Weight 310 lb

RL-10A-4 20,800 lb Thrust
449 sec I_{sp} (Vac)
Area Ratio —
O/F Mixture Ratio 5.5:1
Chamber Pressure —
Weight 370 lb

(The RL-10 data is from a P&W handout which did not give the area ratio and chamber pressure numbers. The new RL-10A-4 uses an extendable nozzle to increase the available area ratio.)

All the above thrust numbers are vacuum thrust.

Mr. SENSENBRENNER. Thank you, Dr. Pournelle. Finally, Bob Citron, President of the Kistler Aerospace Corporation of Edmonds, Washington.

STATEMENT OF BOB CITRON, PRESIDENT AND CEO, KISTLER AEROSPACE CORPORATION, EDMONDS, WASHINGTON.

Mr. CITRON. Thank you very much, Mr. Chairman. Well, it's appropriate that I'm following Jerry Pournelle, because exactly what he says that needs to be done we are doing and we are doing commercially without any government support or financing.

Mr. Chairman, distinguished members of the Subcommittee on Space, thank you for this opportunity to address the very important topic of reusable launch vehicles.

My name is Bob Citron. I'm co-founder and President of Kistler Aerospace Corporation, based in Seattle, Washington.

I'm also the founder of SPACEHAB, Incorporated, a privately financed commercial space research laboratory that routinely flies aboard the space shuttle. And, in fact, next year, four of the eight space shuttle flights will have the SPACEHAB Research Laboratory on board.

Kistler Aerospace is a privately financed company whose purpose is to design, build, test and operate a fleet of fully reusable rocketships and to dramatically reduce the cost of access to space. We are in the process of developing our rocketship fleet with absolutely no government financing.

Our prototype technology demonstrator rockets are currently in development and will begin flight testing in Mojave, California later this year and at White Sands Missile Ranger early next year.

Today, I would like to talk about four issues with you. I may only get through with two because of the time limitation—why we believe we can build and operate fully reusable rocketships using available technology right now; second, why we believe we can do it with all private financing when other companies in the aerospace industry require government financial support.

There are those who question that the technology is currently available to build and operate fully reusable rocketships. However, we believe that we are meeting the critical technical challenges that require resolution in order to build and operate those reusable—fully reusable, not partially but fully reusable—rocketships.

These challenges are not for the faint hearted. But, we have assembled a team of some of the best launch vehicle experts in the world.

And, our team is in the process right now of solving some of the very significant problems that confront a reusable launch vehicle designer and operator. We believe we have the initiative and the flexibility to accomplish our goals.

We believe we can do it because of our good old American way of using available technologies in new ways and our willingness to take big technical and financial risks. We believe, on the business side, we can do it because our management team has a solid track record of developing successful high technology companies. And, this track record has been achieved without any government financial support whatever.

We believe we can do it because we have access to major sources of private financing. Kistler Aerospace is on a fast track. We've raised our first level of private financing.

And, we are developing three subscale technology demonstrator rocketships that are currently in fabrication and testing. Our K-0 demonstrator rockets will begin flight testing this fall at our private Kistler Flight Test Facility at Mojave, California.

Our K-1 fully reusable orbital rocketships are in conceptual design studies. We have 10 work packages under contract out right now.

Our schedule calls for detailed design and definition to take place beginning later this year for the orbital version. Our K-1 fully reusable rocketships will have a capability to put five thousand pounds into low earth orbit, 3,600 pounds to a space station orbit, two thousand pounds into a 700 kilometer polar orbit and 900 pounds on an escape trajectory.

Our company plans to raise 400 million dollars in private financing during the next four years. Our financing sources include private investors, strategic partners, contractors, customers and the equity markets.

We've got a track record before this, because we raised 100 million—more than 100 million dollars in private financing to develop the SPACEHAB Laboratories.

Kistler Aerospace sees a large multibillion dollar commercial launch services market developing, thanks to the emergence for the demand for universal low earth orbit communications systems. These satellite networks will have a profound impact on how people, businesses and nations interact with one another during the coming century.

The explosion of information availability is spawning a vibrant commercial space sector that is projected to grow to tens of billions of dollars per year during the next decade. Even if only a small fraction of the mobile satellite communications constellations actually make it to orbit, there will be a need to launch 30 to 50 satellites each year just to replace those networks every five years.

That market alone justifies the private investment required to develop our reusable rocketship fleet. When you add to this the other emerging commercial satellite launch service markets in remote sensing and scientific and industrial research, along with the government light and medium payloads, you certainly have justification for substantial private investment in what will surely become a very profitable business.

We support government activities on research and development for reusable launch vehicles. We do not support the use of government-developed vehicles for the non-competitive launch of commercial payloads.

Mr. SENSENBRENNER. The gentleman's time has expired.

Mr. CITRON. Okay. Well, in summary, I would just like to say that one of the—one of the points that I haven't gotten to yet that I would like to make is that we are hopeful that the government does not commit to procuring launch services in order to obtain either partial or full funding from industry, which is the direction that NASA is headed right now.

We are hopeful that when our rocketships begin orbital flight operations in about four years—your four year period—that we will be entering a competitive arena on a level playing field and that the government will not have made long-term procurement arrangements with other launch vehicle providers.

And, I would be happy to answer any questions that you have. Thank you.

[The prepared statement of Bob Citron follows.]

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Panel on

Reusable Launch Vehicles

Statement of

Bob Citron
President & CEO
KISTLER AEROSPACE CORPORATION

To the
Subcommittee On Space
Committee on Science
U.S. House of Representatives
F. James Sensenbrenner, Jr., Chairman

The Rayburn House Office Building
Washington, DC 20515-6301

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Seattle, Washington
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Fully Reusable Launch Vehicles

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Today, I'd like to address four issues with you.

First. Why we believe we can build and operate fully reusable rocketships using available technology.

Second. Why we believe we can do it with all private financing when other companies in the aerospace industry require government financial support, government market guarantees, and government termination liability guarantees.

Third. What our position is with regard to current government reusable launch vehicle programs?

Fourth. How the government can help Kistler Aerospace succeed.

First, Why do we think we can do it now?

There are those who question that the technology is currently available to build and operate fully reusable rocketships. However, we believe that we are meeting the critical technical challenges that require resolution in order for us to develop and operate reusable rocketships.

These challenges are not for the faint hearted. But we have assembled a team of some of the best launch vehicle experts in the world, led by Walter Kistler, our chairman and co-founder. Our team is in the process of solving the most significant problems that confront a reusable launch vehicle designer and operator which include the need for high mass fraction, extremely light weight structures, reusable cryogenic propellant tanks, advanced thermal protection systems, protection of the rocket engines during base first atmospheric reentry, the development of a precision landing system, and designing our vehicles for reusability and operability.

- We believe we have the initiative and the flexibility to accomplish our goals. These attributes are not usually found in government bureaucracies or in large corporations.

- We believe we can do it because of our good old American way of using available technologies in new ways and our willingness to take big technical and financial risks.

- We believe, on the business side, we can do it because our management team has a solid track record of developing successful high technology companies. This track record has been achieved without any government financing.

- We believe we can do it because we have access to major sources of private capital.

Kistler Aerospace is on a fast track. We've raised our first level of private financing and we're developing three subscale technology demonstrator rockets that are currently in fabrication and testing. Our K-0 demonstrator rockets will begin flight testing this fall at our private Kistler Flight Test Facility at Mojave, California.

Our K-1 fully reusable orbital rocketships are in conceptual design studies. Our schedule calls for detailed design and definition to take place beginning later this year. We plan K-1 fleet construction, integration, and testing during 1996, 1997, and 1998, and we plan to begin revenue producing orbital flights in 1999.

Our K-1 fully reusable rocketships will have a capability to put 5,000 lbs. into low earth orbit, 3,600 lbs. to the Space Station, 2,000 lbs. into a 700 km. polar orbit, and 900 lbs. on an escape trajectory.

Our company plans to raise $400 million in private financing during the next four years. Our financing sources include private investors, strategic partners, contractors, customers, and the equity markets.

Second, How can we do it with all private financing when other companies claim they can't?

When I founded SPACEHAB ten years ago, we knew that we would need the government as an anchor tenant in order for our company to succeed. We worked hard to develop strong relationships with NASA to meet NASA's requirements, and that has paid off handsomely for both NASA and for SPACEHAB. At the time there was no commercial market for microgravity research and development in space without government sponsorship.

But the situation has changed dramatically for other space business opportunities during the past few years. Kistler Aerospace sees a large multi-billion dollar commercial launch services market developing thanks to the emergence of the demand for universal low earth orbit communications systems. These satellite networks will have a profound impact on how people and nations interact with each other during the coming century.

The explosion of information availability is spawning a vibrant commercial space sector that is projected to grow to tens of billions of dollars per year during the next decade. Even if only a fraction of the mobile satellite communications constellations actually make it to orbit, there will still be a need to launch 30 to 50 satellites each year just to replace those networks every five years. That market alone justifies the private investment required to develop our reusable rocketship fleet.

When you add to this the other emerging commercial satellite launch service markets in remote sensing and scientific and industrial research, along with the government light and medium payload markets, you certainly have justification for substantial private investment in what will surely become a very profitable business.

Third, What do we think about other government reusable launch vehicle programs?

We support government activities on research and development for reusable launch vehicles. We do not support the use of government developed vehicles for the non-competitive launch of commercial payloads.

We were quite excited when BMDO funded the McDonnell Douglas DC-X program. In fact, that program is a big inspiration for us. We're very pleased that NASA is supporting a continuation of the DC-X program and we would hope that the Delta Clipper eventually becomes a reality.

While we are not developing reusable vehicles in the Space Shuttle replacement class and have not bid on the X-33 program, we do favor continued government support of that program. We also enthusiastically support NASA's plans to mature critical SSTO technologies during the next 5 years.

While our company's corporate policy precludes us from bidding on any government contracts, and we understand that NASA may be subsidizing potential competitors through their X-34 program, we believe we have the edge because of our unique proprietary launch vehicle technologies and because of the electronic way we operate our company.

Of course we would like to have the government as a customer when we demonstrate that our technology works and that our reusable rocketships are at least as reliable, if not more reliable, than existing or planned expendable launch vehicles. And, because our rocketships will be fully reusable and operate like a fleet of airplanes, we will offer the lowest launch service prices in the industry.

Fourth, How can the government help us succeed?

We would like to benefit from the results of NASA and DOD R&D efforts and perhaps be influential in specifying areas of research that would be of most benefit to our commercial interests.

We are currently in discussions with NASA on a Technical Exchange Agreement which we hope to have signed during the next couple of months. This umbrella agreement will give our technical teams access to the latest NASA technology research and to specific resources at NASA field centers. We will need some help from NASA with such things as wind tunnel testing, application of computational fluid dynamics to our designs, and thermal protection system testing and evaluation, to name a few.

I would ask this Subcommittee to encourage the rapid transfer of NASA and Air Force technology for use in the development of our reusable rocketships. We also seek the rapid government licensing for our K-1 launch vehicles and for our K-1 launch and landing sites.

We would also hope that the government does not act too hastily in committing to long term launch service agreements in order to get the aerospace industry to partially or fully fund new launch vehicle developments. Taking such a course of action would be unfair to those companies that are proceeding to compete in this arena without the benefit of government subsidy.

We would hope that when the government procures launch services in our payload class, that we be permitted to enter the bidding on a level playing field and not be precluded from competing because the government had already made too many launch service commitments in advance in order to attract industrial financial participation.

Congress continues to grapple with very real budgetary constraints which affect our country's space activities but because we believe there are large profits to be made in space, the private sector is willing to step up to the plate to ensure that we maintain America's leadership role in commercial space development.

Kistler Aerospace does not seek government funding and our corporate policy precludes our acceptance of government funding for any purpose. But we do seek to use the results of government sponsored research and the use of government research facilities. And of course we would like to have the government as a customer at a tremendous savings compared to its current costs of launching satellites.

We seek government cooperation while we are taking large technical and financial risks in an arena which the government has dominated for decades. With the maturing of the industry, that need not continue.

We support the initiatives of this committee and of the Congress for legislation that sparks entrepreneurship in space, including large tax incentives for getting into space and making profits in space.

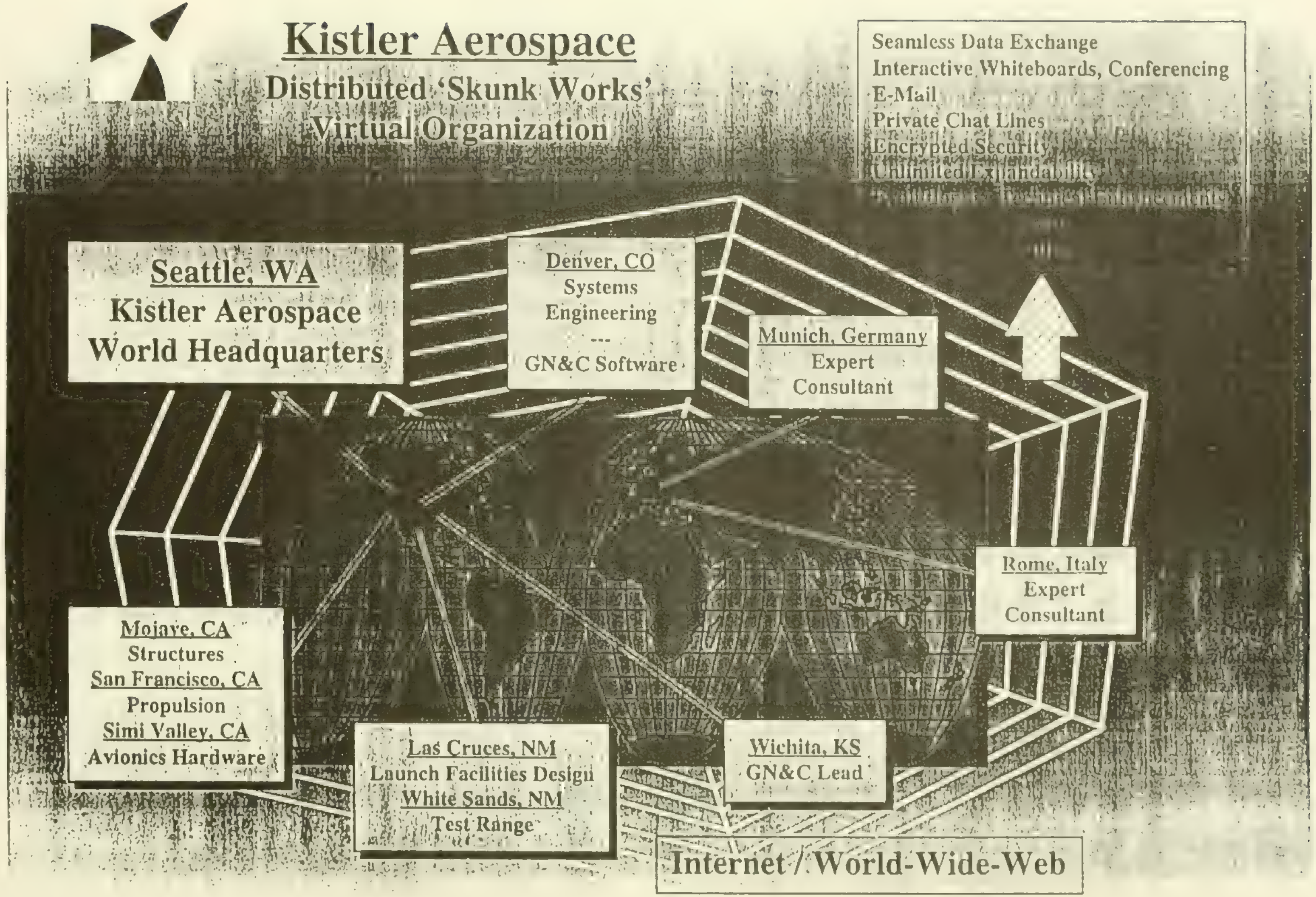
By taking these steps the government can encourage a win-win situation for new, economical launch vehicle development and commercial operation that will not only benefit the U.S. economy but will reduce U.S. government costs and enhance U.S. government flexibility.

Our vision at Kistler Aerospace is to build and operate a fleet of the world's first fully reusable rocketships that will dramatically reduce the cost of launching payloads into low earth orbit. We are doing this by using good old Yankee ingenuity and we believe our success will result in a major expansion of commercial space activities during coming decades.

We feel strongly that our success is one of national importance. We are pioneers in the commercial development of space. Our goal of dramatically reducing space launch costs will benefit societies worldwide and ensure that the United States is at the forefront in providing the infrastructure for the information superhighway.

We have listened and heard the encouragement given by Congress and NASA to commercial interests. We are here today in response to that encouragement and trust there will be appropriate follow-through.

Thank you for inviting me today, Mr. Chairman. If time allows, I would be please to answer questions.



Kistler Aerospace

Distributed 'Skunk Works'
Virtual Organization

Seamless Data Exchange
Interactive Whiteboards, Conferencing
E-Mail
Private Chat Lines
Encrypted Security
Unlimited Expandability
[illegible] Technical Enhancements

Seattle, WA
Kistler Aerospace
World Headquarters

Denver, CO
Systems
Engineering

GN&C Software

Munich, Germany
Expert
Consultant

Rome, Italy
Expert
Consultant

Mojave, CA
Structures
San Francisco, CA
Propulsion
Simi Valley, CA
Avionics Hardware

Las Cruces, NM
Launch Facilities Design
White Sands, NM
Test Range

Wichita, KS
GN&C Lead

Internet / World-Wide-Web

Mr. SENSENBRENNER. Thank you very much, Mr. Citron.

The gentleman from Minnesota, Mr. Luther.

Mr. LUTHER. No questions.

Mr. SENSENBRENNER. The gentleman from Kansas, Mr. Tiahrt.

Mr. TIAHRT. Thank you, Mr. Chairman. Mr. Citron, is it a little bit of a paradox to say that you want to do this with privately funded—as a privately funded effort but yet you are trying to work out a technology transfer agreement so that you can get data from NASA and perhaps DOD, because isn't that already a tax-funded base that you are drawing from in order to do this?

Mr. CITRON. Absolutely. It's the same thing that the airlines did in the early part of this century. They used government tax-supported research and development. And, the NACA provided that kind of data to the aerospace companies, which enabled them to build their fleets of airliners.

And, we, in fact, are currently negotiating an agreement with NASA that will give us access to the NASA centers and research facilities and enable us to obtain some of the research results that we need in order to do certain specific technology developments for our rocketship vehicles. So, we will be using government-supported research and development.

Mr. TIAHRT. As you obtain more access to data, do you have safeguards in place? There is some concern, you know, for national security purposes that some of this information can be used by other countries to perhaps put this country in peril.

So, do you have safeguards in place to accept this type of technology and keep it secure so that when it is used, it's used for the best interest of this country?

Mr. CITRON. Well, we would hope that any technology that is transferred to our program is not classified in any way. We believe that it's possible right now, using existing available technology, the latest cutting edge technology, to develop fully reusable orbital rocketships without going into any kind of classified research.

Mr. TIAHRT. Well, if it's not classified, wouldn't you have access to that under the Freedom of Information Act?

Mr. CITRON. Yes, we do. But, we—some of the NASA centers that are working with our technical teams are now working on some areas of technological research that we need the results from.

As an example, we need to do wind tunnel testing using NASA facilities. We need to do some computational fluid dynamics work done on our designs.

We need to do some thermal protection system testing for our heat shield. And, those are the sorts of things that the government can help us achieve, because they have in place the facilities to undertake that type of research.

Mr. TIAHRT. Thank you, Mr. Citron. I think you are on the right track.

Dr. Pournelle, are you satisfied with the way NASA is carrying out their reusable launch vehicle program?

And, what should the role of the Department of Defense be in that effort?

Mr. POURNELLE. Thank you, sir. Not really. NASA is on the right track. They haven't gone far enough in the right direction.

They tied this procurement, this cooperative notice, to a 25 thousand—the capability to grow this thing and scale it up into 25 thousand pounds to space station orbit. That's stupid.

What they ought to have done is to just look at it as a technology development program. We do not know what the right configuration is to go 25 to—or even whether you ought to go 25 thousand pounds in one lump to space station orbit.

It might well be better to take a ship that flies for three million dollars a flight that takes five thousand pounds to space station orbit and fly it five times than to have one ship that takes half a billion, a flight-like shuttle, and do it all at once.

The point is that—I didn't have much time on this, because I took you people seriously when you said I was supposed to put it in a paper and talk informally. And, I didn't read a speech. Maybe I should have.

Mr. SENSENBRENNER. That's appreciated, Doctor Pournelle.

[Laughter.]

Mr. POURNELLE. But, what I was trying—the point I was trying to make about how we used to be so oriented towards payload, we forgot that the purpose is operations cost reduction. What we really want to do is to be able to get the American citizens into space; where if you take energy and resources and ingenuity, markets will develop, things will happen.

And, so my advice to NASA would be to stop—if I were to give you one piece of advice today, write into the Authorization Act that NASA must be forbidden to think about Shuttle II anymore. They simply have to be told, "You are not going to develop Shuttle II. You are not going to build Shuttle II. You are not going to operate Shuttle II. We don't know how to build it. Go build X planes and go do your job, which is to look at things that are of a long term benefit to the American people but not yet profitable to an individual like Mr. Kistler."

Mr. TIAHRT. Thank you, Dr. Pournelle. I appreciate your—

Mr. POURNELLE. As for defense, let me say one thing on defense if I could, please. I invented a concept called "Thor" 20 years ago.

Take a telephone pole. Make it out of tungsten steel, about 20 feet long, 18 inches in diameter.

Stick a little ball in it. You can roll it back and forth to change the center of gravity. And, put a fin on the back end of it. And, put a global positioning systems receiver in it.

I can then take that thing out of orbit and hit any stationary target on earth with an accuracy of about 20 feet. The closing velocity is around 12 thousand feet per second. And, the effect is as if I buried about two tons of TNT under the target and detonated it.

There is no fall out. There is not even a warhead. It's just impact velocity.

Now, there is no ship, no battleship, no hardened target, there is no bridge abutment, there is nothing in this world that can withstand that. And, that is easily feasible with today's technology.

Now, my son is the missile officer on an Aegis cruiser. And, I don't want him to learn about one of them things by having it come through the deck of his ship.

I would rather the United States of America built those things or that we, at least, are in command of that technology than to discover that some island empire with a grudge has built them.

Mr. SENSENBRENNER. Thank you. The gentleman's time has expired.

Mr. TIAHRT. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentleman from Florida, Mr. Weldon.

Mr. WELDON. Thank you, Mr. Chairman. I apologize for getting here a little late.

I didn't hear Mr. Minor's initial remarks. But, I have a general question and perhaps any of you or all of you could comment on it.

As I understand it, in the history of the shuttle a lot of the philosophical arguments behind the construction of the shuttle were the same as what we are going through today, that we wanted to develop a less expensive way to get into space and we ended up with a more expensive way to get into space. And, my question is: is the way NASA is going about this right now the best way to really achieve that goal?

And, then I have a more specific question for Mr. Citron. I believe you did not respond, and you decided not to participate at all, in the cooperative agreement.

Mr. CITRON. Yes. We don't—we have a corporate policy. We will not bid on government contracts nor will we accept government financing for any purpose.

Mr. WELDON. Why is that?

Mr. CITRON. Why is that?

Mr. WELDON. Yes, because I think it may be related to my first question.

Mr. CITRON. Okay. I can't respond to your first question.

But, the second part is that we enjoy the freedom of totally independent activity. And, we feel that the commercial market—now, when I started SPACEHAB 12 years ago, we knew we needed the government as an anchor tenant, because the government was like 85 or 90 percent of the market at that time. It still is.

But, the commercial market for launching small payloads into space now it looks like that market is going to explode in the next 10 or 20 years. And, we see an opportunity here to raise the private financing to make fully reusable rocketships, a fleet of rocketships, that will reduce the cost of access to space very dramatically.

And, there is no need to get the government involved other than the fact that we do need government facilities help and research. We need access to the government technology research. But, we do not need government financial support.

For us, it's more of a burden than anything else with the government oversight and the contracting. And, we are on a very fast track and can do it very quickly privately.

And, there are private funds available. We are going to be raising nearly half a billion dollars in private financing to do this.

Mr. WELDON. Thank you very much. Could either of you comment on my original question?

Mr. MINOR. Let me say this and hope I got your questions in the right order. First, let me say that I think the approach that the government and NASA is taking on the X-33 and X-34 program is the right direction.

I think it's obvious that I think many companies have bid on those programs. And, it's obvious we have the message from the government that they want industry to be a much larger participant in these programs.

And, I think it's apparent, particularly the X-34 where we are stepping up to a much larger investment than the government, that we have received that message. I must say that things are a little differently than they were back in the 70s from a technology standpoint.

And, I think these vehicles that we are talking about are driven by the commercial sector and the use in that arena. The number of satellites, the number of commercial and communication things that are going on today gives the industry the emphasis because we, frankly, in the long run are in this for business.

And, with some government assist, I think the X-33 and X-34 programs are definitely a step in the right direction.

Mr. WELDON. Did you want to amplify on that?

Mr. POURNELLE. Yes, sir. I can tell you what went wrong with shuttle.

Airlines typically operate at about 110 to 130 employees per airplane. And, about half of those sell tickets.

NASA has something like 20 thousand people involved in keeping three or four vehicles going. Divide those numbers and I think you already start off with the answer.

Shuttle was designed to employ 20 thousand people. It's very difficult to reduce the number of people involved in it, because it was designed to employ them.

That was its purpose. And, it met that goal very nicely.

And, if you let them design a shuttle two replacement, it will meet that goal again. It will employ 25 thousand civil servant development scientists who will form unions.

Do you know that over at NASA Headquarters, if they want to assign office space—they are now laying off some people so they are getting some nice corner offices and things. They can't assign those offices on the basis of merit.

There are union regulations that require them—and we are talking about GS-14s and 15s here, people who make a lot of money—to assign those offices on the basis of seniority. And, that's stupid.

And, as a result, any dang program that is an operational ship built by them is going to end you up with an enormous number of people involved in it, half of them asleep. And, you are not going to get any economic operation.

The purpose of government is to do those things which are not profitable to any one individual and are very profitable to the country as a whole. That is right out of Adam Smith. It's not very left wing.

Mr. SENSENBRENNER. The time of the gentleman has expired.

The gentleman from Michigan, Mr. Barcia.

Mr. BARCIA. Thank you, Mr. Chairman. I don't have a lot of questions.

But, I would just point out to the last gentleman that office space in the Capitol is also assigned on the basis of seniority.

[Laughter.]

Mr. POURNELLE. And, it's stupid here, too, sir.

[Laughter.]

Mr. BARCIA. Mr. Chairman, I just want to compliment you on holding these hearings. And, I don't have any questions at the moment, so I will pass.

Thank you.

Mr. SENSENBRENNER. Thank you very much. The gentleman from Virginia, Mr. Davis.

Mr. DAVIS. No questions.

Mr. SENSENBRENNER. Okay. Well, thank you very much for very interesting and provocative thoughts.

Again, members of the Committee, both present and absent, can send written questions within a week. And, if you receive any written questions, we would appreciate the answers within a week or 10 days.

The fourth panel will be on the subject of aeronautics and technology. We have four witnesses on this panel.

They are: Dr. Jerry Grey, Director of Aeronautics and Science Policy for the American Institute for Aeronautics and Astronautics in Washington; Bob Spitzer, Vice President for Engineering of the Boeing Commercial Airplane Group of The Boeing Company; Dr. Scott Pace, Policy Committee Chairman of the National Space Society in Washington; and Mr. Charles W. Hayes, III, National Program Manager of Cray Research, Inc. in Washington, D.C.

When you are all settled, the first witness will be Dr. Grey. Dr. Grey.

STATEMENT OF JERRY GREY, DIRECTOR, AEROSPACE AND SCIENCE POLICY, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, WASHINGTON, D.C.

Mr. GREY. Thank you, Mr. Chairman. I am here representing the American Institute of Aeronautics and Astronautics, a professional society in the aerospace field. We have 40 thousand members.

I am also, in effect, representing an industry that has a revenue of about 100 billion dollars, contributes 25 billion dollars each year to the balance of trade and in the industry itself sustains over a million jobs. Mr. Spitzer, I think, will refer to these numbers a little bit later on also.

I am here to talk about the proposed national wind tunnel complex. Wind tunnels are critical to U.S. leadership in aviation.

There is a basic difference, however, between most of the wind tunnels in this country which were built for research purposes and the development tunnels which are proposed in the new complex. Development tunnels need to be productive.

They have to be easy to get in and out of so that models can be replaced quickly. And, they have to be operated at low cost, because we need to run a large number of data points in the development process. They must also, of course, do the fundamental—have the fundamental purpose of a wind tunnel.

And, that is to simulate the flight vehicle as closely as possible. In this case, the key factor in that simulation is something called the Reynolds number, which is described at length in our paper and in a background paper.

The proposed national wind tunnel complex does meet the needs of a development type tunnel and also the simulation of Reynolds number and, of course, the mach numbers that airplanes fly at. The big question, however, is not the need for the tunnel.

Everyone kind of recognizes that it would be a very useful thing. But, why should the government support such an activity?

Mr. Spitzer, in a moment, will talk about the potential market for the airplanes that are going to be sold by our industry in this country. And, in today's savage competition, industry simply cannot afford to put up all the money necessary for large facilities.

Classically, the government of the United States has built wind tunnel facilities for use both in their own research laboratories and also for the use of the industry in generating its products. The European countries, in particular, have also invested heavily in wind tunnel facilities.

And, in part, the availability of modern, up-to-date, highly productive development tunnels, which are on line now in Europe, is partly responsible for the growth of their industry. That industry, incidentally, has taken over the world helicopter market. It has taken over the world market in commuter aircraft. And, last year, for the very first time, the Airbus Industrie sold more airplanes than the largest U.S. manufacturer.

So, they are growing. They are growing rapidly. And, facilities are a key element.

Now, government should invest in things that are for the public good. Even Mr. Pournelle says that the government should invest in facilities and in research and development. And, he is certainly a proponent of private sector involvement.

These investments do benefit the U.S. taxpayer. The good old days are really gone. It used to be that industry could stand on its own and sustain a very active industrial position, generating revenue, jobs and all those nice things for the country.

But, today, governments team with their industries in every country in the world. We need to do that if we intend to maintain the kind of revenue, the kind of job conditions that we would like to maintain by maintaining leadership in aviation.

One point I did want to mention, a very important point, is that in searching for the funds that should be made available for this tunnel in which both industry and government certainly should participate, since they both benefit from the investment, two things are important. First, we need to do things differently than we have in the past.

And, there is an industry consortium which has expressed a mechanism for conducting the development of these tunnels in cooperation with the government in an effective way, similar to what is done, incidentally, in Europe and Japan. And, also the concept that some persons have proposed, that perhaps the money for these facilities ought to come out of the NASA research and technology budget, is simply dead wrong, because that budget also is essential for maintaining U.S. leadership in aviation.

We need to find a different mechanism. And, in our paper, I've suggested that.

Incidentally, I would like to request that our paper, "The New National Wind Tunnel Complex," issued last week, be made a part of the record along with my statement if that's at all possible.

Mr. SENSENBRENNER. Without objection, it is so ordered and included.

Mr. GREY. I would like to, incidentally, just quote one final paragraph from our wind tunnel paper. "Although the investment cost of the national wind tunnel complex is considerable, the cost of not developing the facility must also be kept in mind. There is a historical link between technological infrastructures such as wind tunnels and technological advances in aviation. Foregoing the opportunity to develop innovative facilities will put the U.S. aerospace enterprise at a competitive disadvantage, eroding a major source of U.S. strength in the global marketplace and the jobs that go with it."

Thank you, Mr. Chairman.

[The prepared statement of Jerry Grey follows:]

AIAA
American Institute of Aeronautics and Astronautics

Statement to
Subcommittee on Space and Aeronautics
Committee on Science
United States House of Representatives

On the

Proposed National Wind Tunnel Complex

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March 16, 1995

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Mr. Chairman, Subcommittee members, I am Jerry Grey, Director of Aerospace and Science Policy for the American Institute of Aeronautics and Astronautics (AIAA). The AIAA is a nonprofit professional society of over 40,000 aerospace professionals whose mission is to advance the arts, sciences, and technologies of aerospace. We have testified on the civil aerospace program at hearings held by previous Congresses. Our viewpoint is based primarily on the technical considerations that underlie policy decisions concerning the U.S. civil aeronautics and space programs. Because the AIAA represents such a broad spectrum of the aerospace community, it does not reflect the provincial viewpoint of a single constituency, but provides a balanced perspective of the profession as a whole. We welcome this opportunity to comment on the proposed National Wind Tunnel Complex.

Research, development, and operational wind-tunnel facilities are critical to maintaining U.S. leadership in aeronautics. The central recommendation of the aeronautics portion of the National Facility Study, completed in April 1994, was to develop a new national wind tunnel complex (NWTC) consisting of one transonic and one subsonic wind tunnel.

The design of existing research tunnels built and operated by the government (as with other large research facilities) is driven by requirements associated with the collection of scientific data from one-of-a-kind tests. In contrast, development wind tunnels are designed and built to minimize cycle times and costs so that industry can bring new aircraft to market more quickly and at a lower cost than the competition. Development tunnels therefore need not just the aerodynamic features required to simulate accurately the actual flight conditions (such as high Reynolds number, for example), but also high productivity and low operating cost.

The proposed national wind tunnel complex would meet these development needs. Its technical details (including the shortcomings of existing facilities), economic rationale, and policy considerations are discussed at length in a January 20, 1995 AIAA information paper, "The New National Wind Tunnel Complex," released on March 1. 1995. A copy is attached herewith; I respectfully request that it be included in the written record of this hearing.

The value of the NWTC in sustaining one of the nation's most important economic strengths, the aviation industry, is almost universally recognized. That industry employs over a million people, generates over $100 billion in gross domestic product, and produces a positive trade balance for the nation of over $25 billion. But although the U.S. has traditionally led the world in providing technically and economically superior commercial and military aircraft, since the early 1980s the U.S. commercial aviation industry has lost significant market share. World-class aerodynamic test facilities are essential to maintaining and increasing our current leadership. The proposed NWTC represents such a critical asset. It can effect incremental increases in the economic competitiveness of commercial aircraft by enabling technological advances that increase lift and reduce drag and weight, and by improving our ability to estimate aircraft performance in advance of first flight.

The new complex would be able to test models under simultaneous Reynolds number and Mach number conditions close to those experienced in flight. These two parameters permit predictions of full-scale flight vehicle performance through the use of simulated, subscale wind-tunnel models; that is, the closer the wind-tunnel Mach and Reynolds numbers are to those that will actually be encountered by the operational aircraft, the better the simulation of the aircraft's flight characteristics will be.

The flight Mach number is not hard to match, but it is technologically difficult and expensive to build facilities capable of testing large aircraft at -- or close to -- the full flight Reynolds number (a dimensionless parameter defined as the product of flight velocity, air density, and characteristic aircraft dimension, divided by the air's viscosity). Instead, most wind-tunnel testing is performed at lower Reynolds numbers, forcing engineers to extrapolate their data to the flight condition. The inherent uncertainty of this extrapolation requires aircraft design and performance estimates to be over-conservative, precluding industry from utilizing the full value of their aircraft. It should be noted that manufacturers must guarantee performance prior to completing the aircraft design. High Reynolds number testing will reduce the uncertainty and thereby decrease design conservatism.

Industry sources have cited these direct consequences of proceeding with the design and construction of the NWTC:

(1) It will improve U.S. competitiveness due to higher-value aircraft having better performance
  - This will retain high-skill, high-wage U.S. jobs
  - It will contribute significantly to U.S. exports and trade balance
  - It enhances non-jetliner markets (e.g., business jets and engines)

(2) It increases U.S. domestic employment
  - NWTC itself creates over 8100 direct and over 4000 indirect jobs per year
  - Over 6000 direct and over 2800 indirect jobs are created for each 1% gain in U.S. market share

(3) It generates federal tax revenues
  - NWTC investment returns $135 million annually
  - Each 1% gain in U.S. market share returns $120 million more

(4) It reduces environmental impact and energy consumption by enabling reduced engine emissions, noise, and fuel burn

(5) It assures access and data security for U.S. manufacturers, *vs* the need to use foreign-tunnel capabilities

In the past, the U.S. government funded the construction of major wind tunnel facilities for use by both government laboratories and private-sector corporations (which reimburse the government for using these facilities). However, the present budget environment requires a different mechanism for funding the proposed NWTC; for example, it has been suggested that the wind tunnels be designed, built, and financed by a joint government-industry consortium. The amount of investment needed has yet to be determined, but is likely to exceed $2 billion. The source of funds for that investment and the mechanism for sharing it between government and industry are not yet defined.

Some have argued that since the NWTC would benefit the industry, the industry should find the capital needed to build it. Their point is that if industry won't contribute more than, say, 10% of the capital investment, how great can their real need for this facility be? Industry, on the other hand, asserts that the majority of the long-term, low rate-of-return investment required to fund the capital cost of the NWTC should not and cannot be made by the private sector. In the competitive and lean international aerospace market, they say, U.S. industry simply cannot justify even a $2.0 billion short-term cost to gain such very long-term benefits. Also, the need to amortize the cost of the facility would inflate the price of U.S. aircraft, making them less competitive in the marketplace and defeating the whole purpose of the new wind tunnels. (Industry would, of course, pay the full operating costs of using the facility once it is built).

What, then, can we do? The global commercial aviation market is projected at just under a trillion dollars over the next two decades, and it is estimated that every dollar invested in U.S. commercial aircraft generates $2.30 in gross domestic product. Halting the erosion of U.S. market share is therefore increasingly important. The NWTC is one possible means to help halt that erosion.

The mechanism used in Europe is instructive. Unlike their American competitors, European manufacturers of civil aircraft and engines often receive government-sponsored loans to subsidize product research and development. Repayment is contingent on a predetermined level of the developed product's commercial success. A recent General Accounting Office report stated that as of 1990 the French, German, and British governments had invested $13.5 billion in direct support of Airbus Industrie products. By August of 1993 the amount repaid was only $3.5 billion. (Last year Airbus Industrie, for the first time, sold more commercial transport aircraft than the largest U.S. commercial aircraft manufacturer.)

U.S. industry, in contrast, must compete head-to-head with its European counterparts and develop new products without having the government reduce its financial risk. The development costs for new aircraft must be completely underwritten by industry, often resulting in "peak negative cash flows that can exceed the value of the company."

How does this bear on the proposed new wind tunnels? Just as NASA has done in the past, European governments provide major ground test facilities for their industry. During the past 15 years six new wind tunnel facilities were constructed in Europe, and operating-cost shortfalls on their newest tunnels are being covered by Europe's governments until 1997. NASA's charter requires the agency to strive for preeminence in aviation. The proposed NWTC, if constructed, is an avenue by which the federal government could help the aerospace industry, as it has done in the past by building and operating the existing facilities, without providing a direct subsidy. Mechanisms which allow that support off-budget should be considered; for example, long-term, low-interest loan guarantees to an industry consortium which would build and operate the facility. The loans would be repaid from user fees; the tax revenues I mentioned earlier provide an additional (although indirect) "payback" that would help compensate for the low interest rates.

One emphatic point the AIAA has stressed, as have both NASA and industry, is that funding for the wind tunnels must not come at the expense of the existing NASA aeronautics R&D programs: the aeronautics research and technology base, High-Speed Research, or Advanced Subsonic Technology. These programs are critical to the future success of the national aeronautics enterprise and cannot be sacrificed to build the facilities.

In the limited time here, I have been able only to highlight several key issues associated with the proposed NWTC. The attached AIAA information paper is much more thorough and comprehensive. I urge you and your staff to review it. The paper concludes:

> "It is likely that the Administration's leadership will ultimately determine the success or failure of the wind tunnel initiative. The decision will be largely influenced by the final cost of the tunnels, the joint industry-government financing arrangements, and the politics of site selection. In today's tight fiscal environment, the future of the NWTC is still not clear.
>
> "But although the investment cost of the NWTC is considerable, the costs of not developing the facility must also be

> kept in mind. There is a historical link between technological infrastructure such as wind tunnels and technological advances in aviation. Foregoing the opportunity to develop innovative facilities will put the U.S. aerospace enterprise at a competitive disadvantage, eroding a major source of U.S. strength in the global marketplace and the jobs that go with it."

Thank you, Mr. Chairman, for this opportunity to present our views on the NWTC. It is critical to the health of one of the nation's most important economic assets: the aviation industry. I will be pleased to answer any questions you or your colleagues may have.

Mr. SENSENBRENNER. Thank you, Dr. Grey. Next up is Mr. Spitzer from Boeing.

STATEMENT OF ROBERT SPITZER, VICE PRESIDENT OF ENGINEERING, BOEING COMMERCIAL AIRPLANE GROUP, THE BOEING COMPANY, ARLINGTON, VIRGINIA.

Mr. SPITZER. Thank you, Mr. Chairman and members of the Committee for having the opportunity to talk to you about aeronautics today. For the past 30 years, the commercial airplane activities have allowed us to greatly increase the number of people who can travel.

I think about my parents. I think about our families that have all grown up and can now fly on airplanes. And, we've seen it is safe, efficient air travel.

And, the good news is that everyone can travel. The bad news is the market is evolving and changing. We are under tight, economic pressures throughout the industry.

Passengers want and demand more value for their travel dollars. Airlines want lower cost products. And, we want safe, affordable airplanes in service.

The bottom line is that everyone, including the research people, NASA, and industry, are stakeholders in the process of improving the technologies for our airplanes. If we look ahead to the marketplace, we see a growth that will continue to increase.

Our forecasts go out to 2013. And, we see a five percent growth worldwide.

We see that growth increasing in the United States. And, we see that growth increasing in the Asian markets and throughout the world.

And, we see that there is still an opportunity for airplane sales into the future, namely about 14 thousand out into that time period (2013). The United States needs to compete for that market against ever increasing foreign competitions who are helped by their governments.

We advocate that you continue to support NASA's research in aeronautics and provide the technologies that we all need to stay and promote this business. NASA has gained a reputation of being a leader in aerospace technology.

And, it's keenly aware that they are the supplier of aeronautics technology and that we (the industry) are the customer. The communication between NASA and the industry is very good.

And, the technology needs have been expressed and shared in various conferences.

And, I think that between ourselves at Boeing, Douglas, Lockheed, Pratt-Whitney, G.E. and others have met with NASA people and talked about priorities and technology programs. And, the aeronautics program at NASA is very well coordinated among the industry and fully understood by all.

The NASA aeronautics programs that have continued to do that are being addressed. As we go through this program, I would like to address three elements of the research.

In the high speed research area, there is an emerging market for high speed civil transport—a very serious technical challenge but a very serious market challenge.

This could have a very big impact on the future market in the early 21st century. We must know if this airplane is possible. And, NASA leads the leadership on the technologies to understand that.

In fact, if it were not for the HSR-1 and 2 programs, we would not have even a thought of having an HSCT. NASA is to be given the credit for working on the high speed civil transport program and understanding that it must pass all environmental issues and that we have to make sure that the airplane is environmentally sound and can work and that there is a propulsion system to work for that.

That led, with good results, to HSR-2, which is underway at this point in time, to address the technologies of structures, materials, aerodynamics and the likes for the airframe side. We need to find out that if we can make the airplane work, and as technologies are really available and pass the environmental requirements, that this airplane is a technically viable and environmentally sound airplane.

And, the work being done with NASA and industry to explore these highly challenging technologies maybe can give us a chance for an economically viable supersonic airplane.

For advanced subsonic technology areas, I would like to just talk about the fact that the majority of people will be travelling subsonically in the future. And, safe, efficient and affordable air transportation is necessary.

And, with the immense size and importance of this marketplace and technical challenge, NASA is applying its subsonic research in the right areas; namely, reductions in aircraft and airport noise, reductions in emissions, safety of airplanes, capacity in a terminal area, reduce basic R&D development costs, improving simplifying aircraft systems and working on airframe technologies. Requirements for the airplane and the air traffic systems are in the vested interest in the country and in the vested interest of NASA. And, we think that NASA is working on the right activities in that area.

And, the third area that NASA is working on is in national facilities that Dr. Grey talked about. I won't go into the details on the national wind tunnel complex, but it is an industry/NASA joint activity to review and study what we could build in terms of some new national facilities that allow us to be competitive.

I would like to say that the Europeans have put in tunnels. They have more productivity and capability than what we have in the United States. That has put us at some disadvantage.

And, the result is that we are forced to test off-shore and buy time in those tunnels to maintain our position.

At this point, one thing I just want to end with is that we have, I think, a generally good program with NASA in three different areas—in subsonic, supersonic and national facilities. And, Boeing is committed to working its part of the endeavor to build the right airplanes at the right times, to build and manufacture airplanes efficiently and at lower costs to give value to our customers.

And, we believe that the NASA activity to bring along the technology for that matches and provides a healthy economy in the United States.

Thank you very much.

[The prepared statement of Robert Spitzer follows.]

Subcommittee on Space and Aeronautics
Committee on Science
United States House of Representatives

Fiscal Year '96 NASA Aeronautical Research & Technology Budget Authorization Hearing

March 16, 1995

Robert Spitzer
Vice President of Engineering
Boeing Commercial Airplane Group
The Boeing Company

Good morning Mr. Chairman and members of the subcommittee. As an employee of The Boeing Commercial Airplane Group, I am pleased to participate in your hearings on the important subject of aeronautical technology.

My comments this morning will present the following key messages:

- Aircraft programs represent complex high-risk ventures that are accomplished in an environment of constantly changing market conditions, competitive actions and technological alternatives
- Our customers are demanding cost-effective technology that can be used to meet their needs: higher quality, improved operational efficiencies and safety, increased affordability, and reduced order-to-delivery flow times
- The aeronautical industry is a growth business with considerable potential for increasing the economical health of the U.S; however, global competitors also recognize this potential and are aggressively pursuing business opportunities.
- NASA's research program supports the industry's technology need for validated technology and is an investment in a strong U.S.

Market Forecast

Since the advent of the commercial jet age in the 1960s, growth in air transportation has been outstanding and the rate of growth has generally paralleled economic conditions. Economic slumps have occurred, but as global economic problems were rectified, the market for air travel began to bounce back. The growth in 1994 shows that a modest recovery, from the latest economic slump, is in progress.

According to the United States Department of Commerce, between 1983 and 1993 the aerospace industry produced more than $660 billion worth of aircraft, engines and parts. This resulted in a trade surplus of $218 billion, over half of which, $125 billion, was attributable to civil aircraft. Compared to the ten year period that ended with 1992, while the trade surplus was up, civil aviation's contribution was down 18%.

The number of airplanes in service continues to increase. There are more departures, more customers and there is definitely more competition. Travel growth from 1994 through 2013 is forecast to average 5.2%. At this rate, with the need for replacement airplanes included, the market size for new airplanes will double by 2005 and be over 2 1/2 times greater by 2013. International travel is predicted to grow an average of 5.6% per year and domestic travel 4.7%. The growth of air travel will be led by travel to, from and within Asia. These markets account for 25% of world air travel today, but are forecast to account for 41% of travel growth through 2013. By contrast, U.S. domestic travel which is 30% of world travel today accounts for only 20% of world growth through 2013.

Forecasts predict over 14,000 airplane units will be delivered through 2013, an average of 700 per year, or the equivalent of adding a new UAL and Continental every year. Small (737, MD 80, A320 etc.) to medium-sized (767, 777, MD11, A300, A330, A340 etc.) airplanes will constitute two-thirds of all units delivered, and larger airplanes (747, etc.) will account for 58% of all the seat capacity to be delivered. This substantial growth in travel volume (9300 airplanes), combined with the replacement of retired airplanes (4700 airplanes), provides a forecast market of $980 billion (1994 dollars) from 1994 through 2013. Forecasts indicate average delivery dollars per year should run about $49 billion, as compared to the yearly average $21 billion for the past twenty years. We see this passenger and fleet growth occurring in an atmosphere of decreasing yields or cheaper tickets, resulting in the need to provide airplanes with more value to the airlines for the dollars invested.

It is vital to the United States and Boeing that we ensure our continued ability to compete successfully in this future market. Boeing is sensitive to that fact. We are changing our ways of doing business. This includes reorganizing and downsizing to increase productivity to improve the ability of Boeing and our industry to compete for this large global market. We are also taking part in NASA research efforts to ensure that the resultant technology has been validated.

Technology Readiness

Entering the market with a new airplane is like shooting at a target through a set of four moving rings that are aligned only for a second. Sales opportunities emerge when four major criteria are satisfied: the customer projects the need; resources are available; there is financial viability and the technology is ready. Success at hitting the target depends on having the right airplane at the right time at an affordable price. Market leadership is closely linked to preparedness and technology readiness is a key factor.

Ideally, the process of creating new aeronautical technologies, and moving them from laboratories into products, consists of four consecutive stages of effort: scientific research, enabling technology development, technology application studies and development, and product definition. The work shift between stages is not abrupt; work begins on a new stage while the other is being completed. Toward completion of each of the four interrelated stages, studies are carried out to determine whether or not the process can move into the next stage. In moving from scientific research into enabling technology development, feasibility studies are carried out. Between enabling technology development and application studies, validation work occurs. The move from application studies to product definition requires that technology readiness be assured.

For commercially applicable technologies, NASA has traditionally performed the work in scientific research and shared responsibility for the work in enabling technology development. Industry typically performs the work in the latter two phases. The speed with which a technology moves from heavy NASA involvement to heavy industry involvement has a great deal to do with the amount of verification work that has occurred and the amount of risk deemed acceptable by industry.

There is no doubt that the thoughtful application of new technology to our products has made a major contribution to the success our industry has achieved. Now we are taking a broader view of what benefits technology has to offer besides aircraft performance. Industry has to use technology to help meet the goals of affordability, improved quality and greater customer satisfaction. We are in a new era in which NASA and industry must work together to meet those goals successfully.

Customer Demands

At Boeing we are aggressively changing the way we do business. Customizing products to suit customer needs contributed to our success in the '70s and '80s. Today we are actively working with our customers from the earliest stages of design through all the stages of product definition in order to meet their expectations. Customer satisfaction means designing for improved operational efficiency, higher quality, quick delivery and lower cost of ownership. Considering customer satisfaction, the benefits advanced technology has to offer can be grouped into three categories: those that contribute to the process of designing and building the airplane, those that improve the airplane capability; and those that enable capacity growth of the infrastructure in which the airplane operates, including the air traffic management system. Past performance has centered mainly on improving performance. Now the other categories need more attention. With regard to the development and application of the three categories of technology, NASA and industry - which includes the FAA air traffic control function - have responsibilities that are intertwined. The individual responsibilities need to be kept in mind to promote effective interactions.

NASA's Role in Aeronautics

NASA has gained the reputation of being a leader in aerospace technology. To carry out their total space and aeronautics charter they have a dual role to perform. In space activities they are the ultimate customer. They control all aspects of research, product development, production and operate the products as well. Industry is usually involved in all aspects as a supplier.

In aeronautics, NASA's role is different. Instead of one customer/supplier relationship there are several. The traveling public, the airlines, the military, the manufacturers and the researchers all have separate and distinct roles. NASA carries out basic aeronautical research and with industry, provides the resulting technologies, which are then used by industry to define products. The success of this customer/supplier relationship is highly dependant on good communication to facilitate the timely transfer of useable technology.

NASA is keenly aware of its role as supplier of aeronautics technology and similarly aware that U.S. industry is its partner and customer. The communication between NASA and industry, regarding technology needs, is better than it has ever been. Industry is working hard to explain requirements and NASA is working hard to ensure the correct research programs are in place. Since 1992, frank and open discussions have been held to consider needs and priorities. Dan Goldin brought all aeronautical government agencies together with industry leaders (Lockheed, Douglas, Boeing, Pratt & Whitney and General Electric) to confirm technology needs and to establish top level priorities. Subsequent meetings have been held to assess progress and to discuss detail progress and to re-prioritize work when required. The communication channel is working. All that remains is for both sides to concentrate on being good listeners and act on what they hear.

Aeronautical R&T

The NASA aeronautical programs, both those begun in 1994 and those proposed for continuation in the budget for '96, are correctly directed at research and development of high payoff, high leverage technologies, applicable to both the high speed and subsonic regimes. Additionally, results from these same programs will support the underlying assumptions of our growth forecast, that growth will not be constrained by air system capacity and environmental constraints such as noise and emissions. The budget is lean but the right technologies are being addressed during these stages of scientific research and technology development. We believe that the technologies studied in these programs show promise of benefiting U.S. competitiveness.

High Speed Research

The emerging market for a high speed commercial transport represents both an opportunity and a very serious challenge. This high technology airplane of the 21st century will have a profound impact on the long range airplane market, an arena in which the United States is presently dominant.

We must know if, and how soon, the necessary technology can be made available, especially in the areas of propulsion, materials and structures. Without NASA's leadership in the form of the HSR I and HSR II programs there will not be a U.S. HSCT.

NASA is given credit for the formation and leadership of the Phase I efforts in the High Speed Research program. This phase of the program dealt mainly with environmental issues, barriers that might have halted the growth of the supersonic commercial transportation altogether. NASA activities, undertaken in the international arena to arrive at environmental agreements, are to be commended. Phase I results were good, in fact, better than anyone anticipated. It was appropriate that NASA implement the HSR Phase II effort which addresses the technologies that help meet the environmental standards and enable the design of an affordable HSCT.

Other countries have built and operated supersonic commercial transports. They have experience that is invaluable, but the long-range over-water market share will go to the team that can produce an environmentally compatible and economically feasible design. Again, affordability will be the key. The United States cannot build a competitive airplane to fit this market unless industry has access to advanced technology, technology that has successfully weathered the process of maturation. NASA's role in the providing feasibility and validation of key technologies will help the United States move into this new regime of economically-viable flight.

Advanced Subsonic Technology

As growth in air transportation continues into the 21st century, the majority of travelers will be flying subsonically. The need for safe, efficient, affordable air transportation will be even greater as the number of flights and aircraft departures continue to grow and the burden on the air traffic control system increases. The National Research Council's Aeronautics and Space Engineering Board stated that maintaining our global competitiveness in commercial jet transports should be one of the key objectives of the NASA's aeronautical research.

Given the immense size and economic importance of the subsonic commercial transport market and the technical challenges, we should proceed aggressively with research applicable to this class of aircraft. The NASA Subsonic Initiative is aimed at doing just that. Significant research being conducted includes, 1) reductions in aircraft and airport noise, 2) reductions in aircraft emissions ensuring safety of aging aircraft, 3) increased air capacity and terminal area productivity, 4) improved aircraft analysis tools and methodologies to reduce risks and flow times, and 5) improved airframe and aircraft systems.

Requirements for airplane safety and efficiency will be even greater as air transportation expands, increasing the burden on the total air transportation system. If the U.S. invests in advanced technology for commercial airplanes, but does not improve the system in which those airplanes operate, there may be very limited return on the investment. In 1988 the Office of Science and Technology Policy (OSTP), Aeronautical Policy Review Committee, identified "the development of a next-generation global air traffic control system as the most pressing issue." In August 1993, a report to the President and Congress from the National Airline Commission reported that the air transportation system has become essential to economic progress for the citizens and businesses of this nation, and identified a need for efficiency and technological superiority to be adopted; and in September 1994 The Office of Technology Assessment (OTA) report stated ". . . to better anticipate new safety and efficiency challenges to the aviation system and to promptly modernize the U.S. Air Traffic Control (ATC) system, federal aviation research and development (R&D) must encompass more than technology." We need a new approach in applying technologies to the system. NASA's initiation of an advanced air traffic technology effort within the Advanced Subsonic Transportation Initiative is an important step in addressing this issue.

Achieving a good air transportation system design is not an issue to be handled by the NASA alone. We see it as a major effort with serious global, as well as national, impact. Besides the obvious involvement of the FAA and the DOT, the numerous industry stakeholders will need to play key roles. There is a need to establish a high-level national commercial aviation forum for addressing interrelated issues that require policy guidance.

Deregulation of the U.S. airline industry, and the resulting cost pressures on the industry, have significantly increased the importance of airplane manufacturing cost. NASA has recognized this need by incorporating an Advanced Design and Manufacturing effort in the AST program.

National Facilities

Wind tunnels are crucial to the development of new and derivative aircraft. Data from these facilities help to define the configuration and provide confidence when offering the airplane to potential customers. Since offers are made prior to program go-ahead, and include performance and price guarantees, high quality wind tunnel data is needed to support early decisions.

Wind tunnel tests validate the airplane performance predictions, determine off-design flight characteristics, support simpler and lighter designs and are the least costly method of measuring flight characteristics and performance. It provides a unique integration of all aerodynamic forces and moments on the airplane. The limitations of wind tunnel simulation revolve around the issue of predicting full scale airplane flight by extrapolating the data from a much smaller model in a confined flow. To gain a better understanding of three dimensional flows and the forces involved, the size of the model must be increased without sacrificing the ability to simulate air flows at cruise speeds. This is essentially what the new wind tunnel designs have done by incorporating what is referred to as higher Reynolds Number conditions. Testing at higher Reynolds numbers is particularly important for larger airplanes: the payoff in performance is substantial.

With the implementation of new European wind tunnels having both improved productivity and the capability to test at higher Reynolds number, U.S. industry has been placed at a disadvantage. We are forced to test off-shore and buy time in foreign tunnels as they can be made available. Modern wind tunnels have given the Europeans a powerful chip to play in the games of global partnership and competitiveness. Obviously, the availability of new wind tunnels is a key factor in the ability of U.S. manufacturers to remain competitive. We need timely access to modern tunnels.

NASA has been chartered to maintain U.S. leadership in aeronautics and space. The maintaining of state-of-the-art national experimental test facilities is one of its proper roles. Until the early 1980s, NASA facilities were the best in the world. This is no longer true.

Boeing and other industry members continue to work closely with NASA on the technical requirements for new wind tunnels. We are also working cooperatively on a plan for design and construction of low speed and transonic wind tunnels.

We recognize traditional approaches to the acquisition of new national facilities may not work. Therefore, both NASA and industry are examining new, novel approaches that recognize our individual constraints. One of the key elements of this model is the utilization of commercial business practices for siting, designing, contracting, building and operating the wind tunnel facility.

It is recommended that the first phase of these studies be completed prior to a final decision on a new wind tunnel complex

Summary

Between now and the year 2013, a forecasted $980 billion dollar market is at stake. Competition for this market will be intense. The ability of the U.S. commercial aeronautical community to continue as a major contributor to the country's economic health hangs in the balance. The leadership provided by the NASA/Industry team may be the important difference in determining who wins and who loses.

At Boeing, we are committed to meeting this challenge head on. Our available resources are being invested to further technology efforts, as well as to improve development and production facilities, processes and methods. We are improving existing products and exploring new products, including a high-speed commercial transport. The Boeing goal is to improve quality while lowering costs, reducing flow times to provide products with features that the airlines value. In regard to this goal, we need NASA's help in making the right technologies available at the right time.

We welcome the continued opportunity of working with NASA as a team. We believe the NASA multi-year research program, initiated in FY '94 and proposed for continuation in FY '96, is the right program. It is a lean program that addresses the high leverage, high payoff technologies needed for future competitiveness. We recommend that you approve the FY '96 budget request.

Thank you, Mr. Chairman.

Mr. SENSENBRENNER. Thank you, Mr. Spitzer. Next up is Dr. Pace from the National Space Society.

STATEMENT OF SCOTT PACE, CHAIR, POLICY COMMITTEE, NATIONAL SPACE SOCIETY, WASHINGTON, D.C.

Mr. PACE. Thank you, Mr. Chairman. It's a pleasure to be here today.

And, I appreciate the opportunity to provide some of the views of the National Space Society which represents people who have a stake in the future development of space but who are not part of the traditional NASA and contractor community, but are a grassroots organization of American citizens and others around the world.

The National Space Society is dedicated to the creation of a space-faring civilization and the visionary development of communities beyond the earth; that is, the other end of the NASA development effort, beginning with aeronautics and hopefully ending with space exploration and human settlement of the solar system. The barriers to space development are many, but we see them as two general categories.

One of them obviously is immature technologies. We simply don't have some of the capabilities we need to do that vision.

The second category is government policies. And, the National Space Society is working to address both government policies and technologies that are necessary for space development.

NASA's technology efforts, we believe, should focus on developing capabilities to use local resources in space and to work with industry to lower the cost of access to space, to create the tools necessary for space based industries. The ultimate purpose of NASA, if one was to really think of what would be an ambitious effort for them, is to create the tools and gain the data necessary to empower individuals and private organizations to make their own decisions in going into space.

Just as NASA pioneered efforts in aeronautics and the government pioneered efforts in government policy to create the tools and information necessary for private firms to build aircraft, operate aircraft and service the world economy, ultimately the purpose of NASA should be to develop the technologies and tools and to work with the government to develop proper policies so that individuals and private organizations can make their own decisions about going into space and so that space is not permanently the preserve of well-trained and compensated civil servants of whatever government.

NASA needs to do more with industry than just have conferences and let out contracts, important as those may be. U.S. industry partners should be setting priorities for the demonstration and qualification of new technologies.

The need for infusing new technology, especially from the commercial sector, is crucial to lowering the cost of government operations. I should point out that NASA has an exemplary record in the case of the aeronautics program in terms of working with industry. That record, however, has not always found its way over to the space side of the house.

The National Space Society (advocates) key enabling technologies for space development that at present have limited commercial markets. Examples for this for NASA as a lead role include things like life support systems and non-materials processing; that is, using local resources such as the potential for water ice on the moon to lower the cost of supporting space operations from earth.

Other technologies such as space nuclear power, which right now is dying on the vine for lack of interest and lack of missions, are crucial for long-term development of the space operations. And, we believe they should be pursued either by NASA alone or hopefully in cooperation with other agencies.

One of the most difficult challenges, however, is not just technology but is in rethinking the system of incentives within NASA for developing new technologies. We believe the government should help create incentives for developing and qualifying new technologies for use by the private sector and particularly the technologies for human settlements.

The National Space Society has advocated several mechanisms such as vouchers, prizes, and tax exemptions for space activities. We believe in these kinds of steps but frankly, they are experiments. We don't know which or if all of them will work.

But, these experiments can help create the positive, regulatory, legal and financial incentives that will foster new space technologies. And, again, we hope from the private sector and in cooperation with the private sector.

In a time of declining NASA budgets, the current NASA field center structures obviously will have to change. And, in the end, one may imagine a NASA that looks more like ARPA with other government agencies, privatized space operations and commercial industry, the ultimate customers for NASA technology programs, rather than simply in-house NASA consumption, again as important as that may be.

We are past the Cold War. We are in a period of declining budgets.

And, in the last Administration, the National Space Council sponsored a study on the space industrial base, sometimes known as the "Fink" report. And, the number one recommendations of the Fink report was that NASA and the DOD work at forging better relationships with each other, cooperation in common technologies.

Now, this does not mean things like the National Launch System, much of which I think is a painful memory to people in this room. But, it does mean cooperation in common technologies and materials and propulsion and taking advantage of the talent that is there in the government and is outside of NASA.

In a time of declining budgets, we don't have the time or energy to waste neglecting any source of talent. And, new relationships between the DOD and the DOE structures, I think, can help infuse NASA with new energy and new hope for the future.

And, in that, I would like to turn to any questions that you may have at your convenience, sir.

[The prepared statement of Mr. Pace, with attachments, follow.]

NATIONAL
SPACE SOCIETY

PREPARED TESTIMONY OF DR. SCOTT PACE
CHAIR, POLICY COMMITTEE, NATIONAL SPACE SOCIETY

BEFORE THE U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SUBCOMMITTEE ON SPACE AND AERONAUTICS

NASA: THE OUTSIDE OPINION
AERONAUTICS AND TECHNOLOGY PANEL

MARCH 13, 1995

MR. CHAIRMAN, MEMBERS OF THE SUBCOMMITTEE:

I would like to thank you, Chairman Sensenbrenner, and the other members of the Subcommittee on Space and Aeronautics for providing this opportunity to testify today. This is a time of great uncertainty and challenge for U.S. and international space activities and we appreciate your efforts to hear the views of persons outside of NASA and the traditional contractor community who also have a stake in the future of space exploration and development. I am speaking on behalf of the National Space Society and my views are not necessarily those of my employer or clients.

The National Space Society

The National Space Society is dedicated to the creation of a space-faring civilization and the establishment of communities beyond the Earth. Our mission is to promote change in social, technical, economic, and political conditions when people will live and work in space. We believe that the technologies and industries created on the space frontier will be of benefit to all humanity in the coming century. We further believe that opening the space frontier will create new opportunities for human life, liberty, and the pursuit of happiness.

Space activities today are still largely driven by governments. In the United States, the NASA budget was about $14.5 billion, reported military space activities were about $15.1 billion, and commercial space revenues were about $6.5 billion.[1] Yet total commercial space revenues have been growing at an average of 20 per cent per year for the

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[1] Library of Congress, *Military Space Programs: Issues for the 104th Congress*, Marcia S. Smith, Congressional Research Service, 95-95 SPR, January 11, 1995;
U.S. Department of Commerce/International Trade Administration, *U.S. Industrial Outlook, Chapter 28 - Space Commerce*, U.S. Government Printing Office, Washington, D.C., January 1994.

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last five years, some years being better than others. In contrast, U.S. government space spending will stay flat at best in constant dollars and will more likely decline. This is certainly true of NASA and may be true for the Department of Defense as well. What this means is that commercial space revenues from communications, remote sensing, and satellite navigation (e.g., the Global Positioning System) will increase in importance. At current growth rates, commercial space will account for 40 per cent of U.S. space spending in the year 2000 - five years away. If the growth rate drops in half, to 10 per cent per year, commercial space will still account for 28 per cent of U.S. space spending.

The National Space Society does not believe that the settlement of the Solar System can be accomplished with any single government program or even the cooperative efforts of many governments. Rather, space development and settlement will occur most effectively when the economic, technical, and social conditions allow individuals and non-governmental organizations (such as private firms and non-profits) to move into space on their own. The barriers to space development are many, but they can be put into two general categories: 1) immature, expensive technologies; and 2) government policies. The National Space Society supports efforts to remove both kinds of barriers.

There are many possible outcomes for the future of space development. In his book, "Humans in Space - 21st Century Frontiers," Harry Shipman poses two cardinal questions.[2] First, can extraterrestrial resources be used to support humans in space? Second, will space industrialization work? That is, can we "live off the land" and can we produce something of value to pay our way. If the answers to both questions are yes, than space settlement can occur. If the answers to both questions are no, then space is a realm for science and a few important, but earth-focused missions such as weather monitoring. If we can live off the land, but not produce anything of value, then space will be like Antarctica - a place for research and tourism, but not much else.

The members of the National Space Society believe the answers to both questions are yes. But belief is not the same as knowing. The answers to these questions produce such dramatically different outcomes for the future of space development that a modest level of public effort should be dedicated to answering them. I should point out that the Congress has already laid the basis for such efforts with passage of the 1988 Space Settlements Act.[3] This

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[2] Harry L. Shipman, *Humans in Space - 21st Century Frontiers*, Plenum Press, New York, 1989.

[3] Public Law 100-685, sec. 217; 102 Stat 4094; codified at 42 U.S.C. 2451 (1988)

Act declares that "the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements." is a national goal requiring periodic reporting by NASA regarding how its programs are to advance this goal. With the exception of one report during the ill-fated Space Exploration Initiative effort, NASA has failed to provide the required reports to the Congress.

The lack of NASA reporting on progress toward space settlements is in part understandable. As long as such efforts were seen as requiring hundreds of billions of government-supplied dollars over decades, it was clear that the necessary political support would hardly be forthcoming after the end of the Cold War. NASA needs to recognize that it will not settle the space frontier any more than the Department of War and the Department of Agriculture settled the American West. Even in the present tough fiscal environment, NASA can, make valuable contributions to answering the questions I've poised. NASA's technology efforts should focus on developing capabilities to use local resources in space, and working with industry to lower the cost of access to space and create the tools necessary for space-based industries. For example, the proposed Lunar Prospector mission could provide definitive information about potential resources on the Moon for a modest $73 million (including launch.)[4]

In a time of down-sizing and reduced resources, NASA needs to decide what it's core competencies should be and how to maintain them. This debate is well under way so let me be blunt. Many proposed NASA missions could, in the extreme, be done by other agencies. Science, environmental monitoring, even space operations themselves, could be done by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the Department of Defense; although the character of these operations would change to match their new homes. Space science and technology are the core of NASA but it is unclear what purposes this capability should serve. In a March 6 editorial, the New York Times said that the "space station makes minimal sense unless it is part of a broader plan of space exploration."[5] This is a vulnerability at the heart of NASA. A way must be found to give NASA a new post-Cold War purpose in light of fiscal realities or this unique agency will sooner or later close shop.

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[4] James Asker, "Moon Mission Set for 1997," *Aviation Week and Space Technology*, March 6, 1995, pp. 18-20.

[5] *New York Times*, Editorial March 6, 1995, pg. A14

The National Space Society is not by definition a NASA supporter. Rather, we are supportive of NASA as their efforts coincide with our goals. **We suggest that a unique, post-Cold War role for NASA can be found in developing the technologies and gaining the data necessary for human expansion into the solar system. The ultimate purpose of NASA should be to empower individuals and private organizations to go into space for their own reasons.** This can be down even with the constricted budgets expected of the next few years. As NASA Administrator Goldin has recognized, it is precisely the pressure of these budgets that create the incentives to think anew about a sustainable, long-term future for NASA.

NASA Technology Programs

NASA has historically spent few resources specifically for developing new technologies. Other budget categories such as Space Transportation, Science, and Construction of Facilities, have always been a larger component of NASA spending. Technology efforts tend to get short changed during tight budgets in the squeeze created by institutional overhead, current operations, and the desire for new program starts. Like the federal budget itself, entitlements tend to crowd out discretionary spending.

Technology programs have been better funded in recent years as NASA has begun focusing on the need for developing and qualifying new space technologies. These efforts have had various names such as Pathfinder, Integrated Technology Plan, and now the New Millennium Initiative. In fiscal year 1996, the Administration is requesting almost $500 million for the New Millennium Initiative for programs such as small spacecraft technology and the small booster technology testbed. These programs are intended to facilitate the infusion of new technologies into future science missions and launch services.

The need for infusing new technology, especially from the commercial sector, is critical to lowering costs of government operations. As the Department of Defense has also discovered, the product life-cycles for commercial technologies are shorter than that of government procurements. It's no wonder that NASA often finds itself playing catch-up. For example, it wasn't until 1990 that microprocessors were first used as flight critical elements on the Shuttle in the Extended Duration Orbiter program. It now takes years to get NASA certification for approved parts and vendors. A 30-month lead time is a common requirement for parts from space-qualified vendors. Getting faster, cheaper, and better space missions must address the technologies, parts, components, and paperwork that are required by those missions.

The National Space Society has called for supporting key enabling technologies for space development that at present have limited commercial markets. Example technologies for a lead NASA role include life support systems and non-terrestrial material processing. Other technologies, such as space nuclear power, may be pursued by NASA alone or in cooperation with other agencies.[6] Finally, some technologies, are still in a generic, pre-competitive state where NASA may be only one potential user among many. An example of this situation is molecular manufacturing in which devices are built by the manipulation of individual atoms to precise specifications.

It is not enough that a key enabling space technology exist or that it be demonstrated. The knowledge of how to use it must be present in industry and available to new firms. Large aerospace firms maintain proprietary databases of space-qualified parts, components, and materials that they have learned to use through hard and expensive experience. These databases are competitive advantages to the firms that have them, but they also constitute a barrier to lowering costs and encouraging new firms to compete. Like the secrets of a medieval guild, the practical application of space technology remains guarded intellectual property. We have nothing against private firms developing and protecting their intellectual property, but we would like to see greater efforts in organizing, qualifying, and publishing the results of government technology demonstrations.

NASA needs to do more than just have conferences and contracts with industry. U.S. industry partners should to be setting priorities for the demonstration and qualification of new technologies. NASA's predecessor, the National Advisory Committee on Aeronautics (NACA) published catalogs of airfoil cross-sections and data on wind tunnel performance. Wing designs to be tested were developed in close collaboration with industry and government facilities were used to gather test data and publish the results. Nothing similar exists in the public domain for firms seeking to develop satellites and space launch systems. This may be an intentional result from the fear of foreign competition and export controls to prevent missile proliferation. It may be an intentional result of the need of existing firms to protect their competitive positions. In any event, we believe it is important the NASA technology programs not just develop and demonstrate new technology, but that priorities be set in consultation with industry and the results to organized and disseminated widely to any legitimate organization.

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[6] Space nuclear power is be vital for long-term, deep space missions by robots or humans but the Department of Energy seems to be abandoning its efforts in this area and there are few (legal) commercial markets for this technology.

One of the most difficult challenges is rethinking the system of incentives within NASA for the development of new technologies. Dan Goldin has encouraged risk-taking in new technologies and the New Millennium Initiative Program, but his leadership is not enough. How can the government create incentives that result in the development and qualification of new space technologies, and in particular the technologies for human settlements in space? More than government programs are needed and the National Space Society has advocated several mechanisms to foster innovation. Vouchers could be offered to researchers seeking suborbital and orbital launch services rather than have them tied to the Shuttle as a "free" good. Prizes could be offered for particular space achievements, such as those that contribute to human self-sufficiency in space. Space could be designated a tax free zone for activities involving on-site employment, manufacturing, or the provision of in-space services. While moving away from specific technology developments, these steps could help create positive regulatory, legal, and financial incentives for the development of new technologies. As we have said on many occasions, the economic barriers to space development stem from both technical and governmental sources.

In a time of declining NASA budgets, the current NASA field center organizations will have to change. We think it would be a mistake to focus on a symbolic effort to close one or two field centers as that would not really attack the fundamental problems of duplication and inefficient competition in the center system. NASA is rethinking the core competencies it wishes to retain and how to align the centers accordingly. This is a good first step, but we hope NASA will go further and seek to spin off operational roles such as Shuttle processing, suborbital rockets, the Tracking and Data Relay Satellite System, and even the Space Station (after it is completed) to private operators.[7] As the centers focus more on R&D, we would encourage the formation of close university relations to ensure the most effective type of technology transfer: students who leave and go to work in industry. It is likely that major portions of the center system will be closed and consolidated. In this process, we would like to ensure there are mechanisms that allow smaller, innovative elements within the center system to compete effectively for resources. In the end, NASA

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[7] For example, the mature operation of the Space Station could be managed by an international institute in association with universities and private industry.

may look more like ARPA, with other government agencies, privatized space operators, and commercial industry the ultimate customers for NASA technology programs.

The Potential of Space Technologies

The primary capability needed for any expansion of space activity is, of course, space transportation. We have probably all heard about the importance of lowering the "cost per pound" for getting into orbit. This is a crucial point, but for a really exciting future, humans will need to be able to move about the solar system rapidly as well as cheaply.

Let me illustrate the possibilities that could occur with one major breakthrough. Today, spacecraft heading for the planets are given a starting boost by their rockets and they then coast to their destinations over months or years, making mid-course corrections, and then possibly firing a small burst to put themselves into a parking orbit about their destination. But what if it were possible to build a spacecraft that could accelerate continuously, say at 1/100 of earth's gravity? At 1/100 "g" a round-trip mission from Earth to Mars and return would take about 46 days instead of months. A mission from Earth to Pluto and back would take about 46 weeks. If our fictional ship could maintain an acceleration of 1 earth gravity for the entire trip, that is, with the same force as we now feel sitting in this room, the time for a round-trip to Pluto would be 4.6 weeks and the time to Mars and back only 4.6 days - or less than a week.

While Pluto is 50 times farther away than Mars in distance, it can be only 7 times farther away in time. The catch here is that we do not know how to build a constant boost ship but there is no law of physics that says we cannot. There is no shortage of interesting ideas on approaches to building high speed interplanetary vehicles, such as using powerful laser beams, surplus nuclear explosives, or even manufactured antimatter in minute quantities.[8] The hydrogen/oxygen engines of the Space Shuttle are impressive but they need not be the last word in space propulsion.

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[8] For an overview of antimatter research and potential applications, see B. Augenstein, B. Bonner, F. Mills, and M. Nieto, ed., *Proceedings of the RAND Workshop on Antiproton Science and Technology, October 6-9, 1987*, (Teaneck, NJ: World Scientific, 1988). The energy conversion rate for antimatter is about 44 kilotons of high explosive per milligram.

Another exciting area of technical potential is that of nanotechnology.[9] In the near term, micromachine technology may allow the building an interplanetary spacecraft at the size of a small desk. "Molecular manufacturing" or the precise manipulation of matter at the level of individual atoms may allow us to go further and that same interplanetary spacecraft could shrink to the size of a laptop computer on that desk. Molecular manufacturing is similar in many respects to molecular biology. In cells, molecular machines make biological components. In molecular manufacturing, molecular machines will make engineering components. Systems to guide molecular level assembly and the precise control of chemical reactions can help minimize waste and defects, producing systems of uniquely high quality. This can mean aerospace structures with over 70 times the strength-to-weight ratio of aluminum. It can mean being able to place the computing power of a billion modern workstations in a desktop package - while producing less waste heat than a light bulb.

The beginning of the industrial revolution was characterized by massive, wasteful, inflexible machines. Old technology did not conserve resources but consumed them, creating pollution along the way. Today, technologies are available which can create the things we need with dramatically fewer resources and waste. The next century could see the flowering of a new manufacturing revolution, symbolized by tiny, efficient, and intelligent machines traveling outward from the Earth to explore new worlds. Hopefully. with humanity close behind.

Summary

- The National Space Society is dedicated to the creation of a space-faring civilization and the establishment of communities beyond the Earth.
- The barriers to space development are many, but they can be put into two general categories: 1) immature, expensive technologies; and 2) government policies.
- NASA's technology efforts should focus on developing capabilities to use local resources in space, and working with industry to lower the cost of access to space and create the tools necessary for space-based industries. The ultimate purpose of

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[9] For a technical overview of nanotechnology, see K. Eric Drexler, *Nanosystems: Molecular Machinery, Manufacturing, and Computation*, (New York: John Wiley and Sons, 1992).

NASA should be to empower individuals and private organizations to go into space for their own reasons.

- **NASA needs to do more than just have conferences and contracts with industry. U.S. industry partners should to be setting priorities for the demonstration and qualification of new technologies. The need for infusing new technology, especially from the commercial sector, is critical to lowering costs of government operations.**

- The National Space Society advocates supporting key enabling technologies for space development that at present have limited commercial markets. Example technologies for a lead NASA role include life support systems and non-terrestrial material processing. Other technologies, such as space nuclear power, may be pursued by NASA alone or in cooperation with other agencies.

- One of the most difficult challenges is rethinking the system of incentives within NASA for the development of new technologies. The government should create incentives for developing and qualifying new space technologies, and in particular the technologies for human settlements in space. The National Space Society has advocated several mechanisms such as vouchers, prizes, and tax exemption for space activities. These steps can help create the positive regulatory, legal, and financial incentives for new space technologies.

- In a time of declining NASA budgets, the current NASA field center organizations will have to change. In the end, NASA may look more like ARPA, with other government agencies, privatized space operators, and commercial industry the ultimate customers for NASA technology programs.

Thank you.

Appendix I

National Space Society Briefing on

Human Expansion into the Solar System: Issues for U.S. Space Policy

March 3, 1995

(Attached)

Human Expansion into the Solar System: Issues for U.S. Space Policy

March 3, 1995

Dr. Scott Pace, Senior Vice President
National Space Society - Washington, D.C.

The National Space Society

What is the National Space Society?

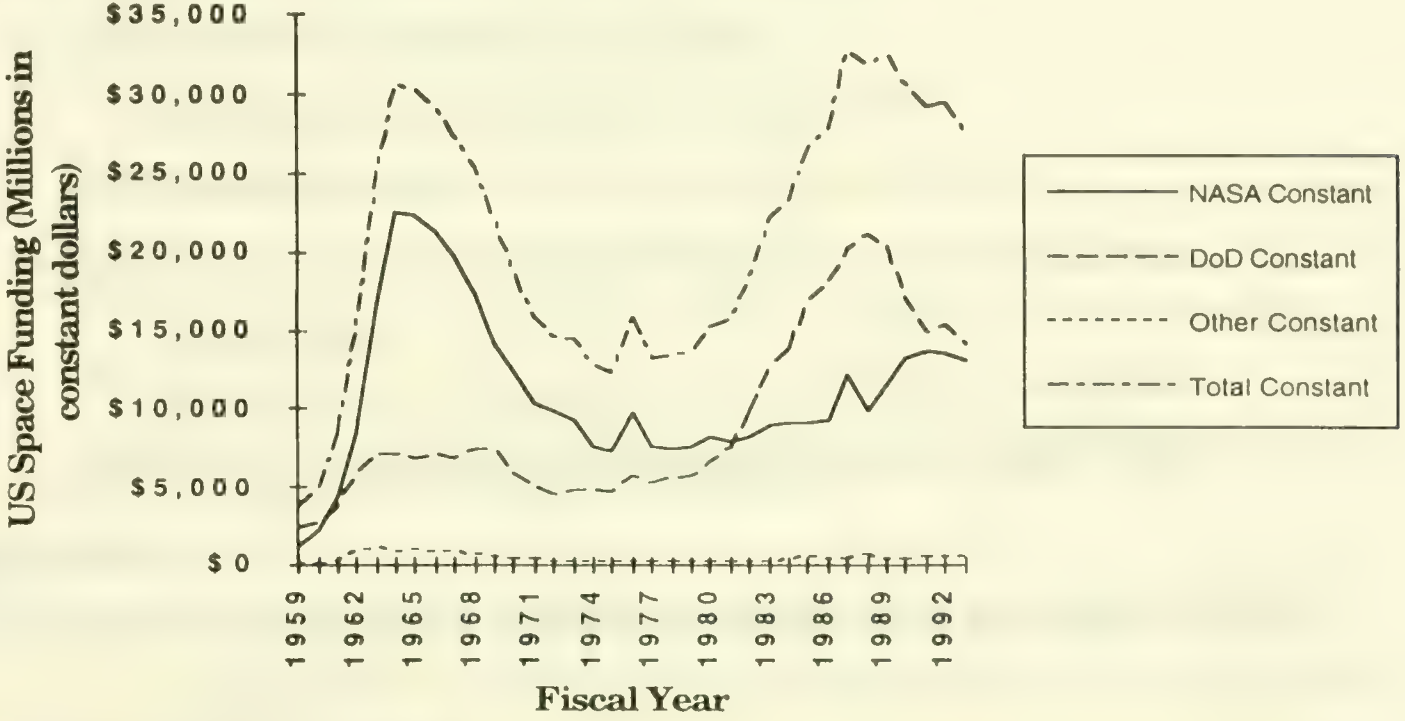
- A non-profit, educational organization
  - Over 25,000 members in all 50 states
  - 75 chapters in the United States and overseas
- Publisher of “Ad Astra” magazine
- Part of a family of organizations with Spacecause and Spacepac
- Vision:
  - The creation of a space-faring civilization and the establishment of communities beyond the Earth
- Mission:
  - Promote change in social, technical, economic, and political conditions to advance the day when people will live and work in space

What is the Government's Role in Space?

To Serve the Public Good in ways the Private Sector Cannot:

- National Defense and International Security
  - international cooperation and competition (including exploration)
- Basic Science and High-Risk Technologies
- Public Services
  - weather and environmental monitoring
- Promote economic growth
  - stable legal and regulatory environment
  - customer of commercial goods and services

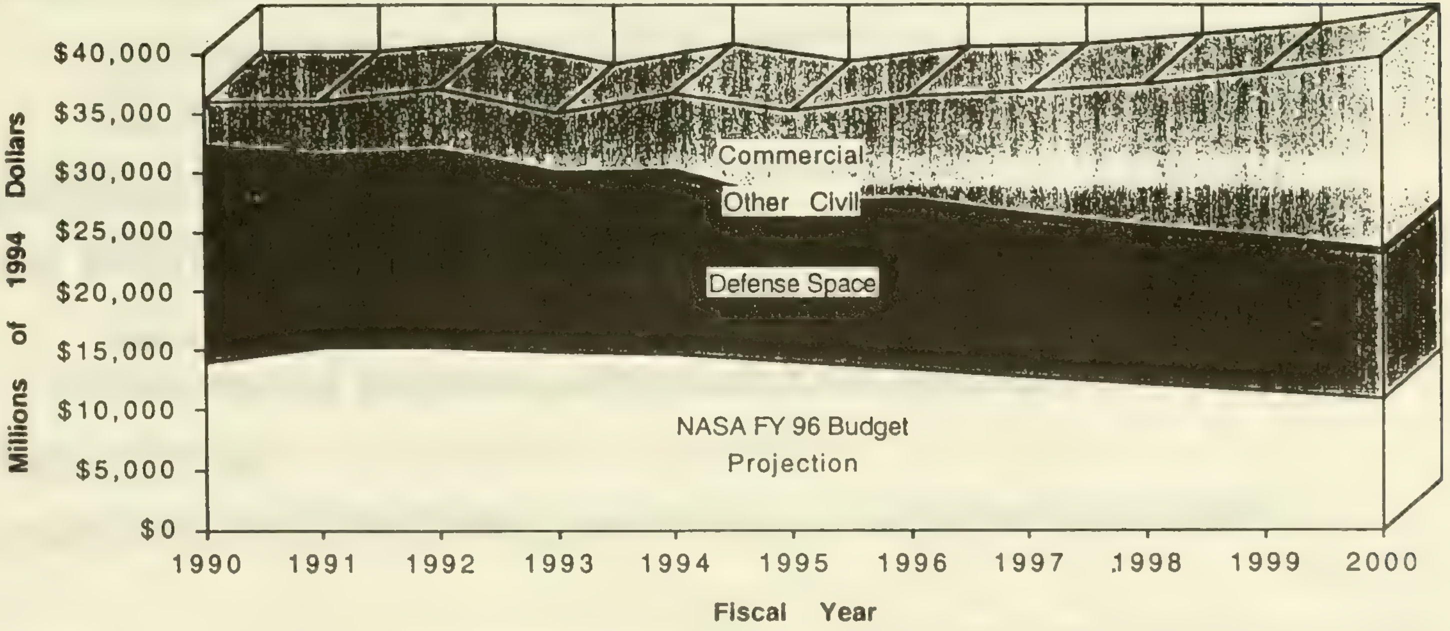
Historical U.S. Space Budgets



Source: Air Force Magazine/August 1994

Commercial Space is Growing

U.S. Space Funding and Commercial Revenues



Average 5-year Space Commerce Growth was 20%

Challenges for the Space Communities

- Government budget limits will continue and may get tighter
  - international and commercial resources need to be attracted to space projects
- All sectors need lower cost, more reliable access to space
  - many promising, but uncertain choices
  - the Space Shuttle is showing its age
- International cooperation is an issue for all sectors
  - the future of Russian space capability is still unsettled

Next Steps in Space

- **Commercial growth will continue to strengthen**
  - space is part of the global information industry
  - communications, remote sensing, navigation technologies are blending in the market
- **International military ties in space will increase**
  - driven by budgets and common interests
  - increasing use of commercial technologies
- **The future of human exploration is uncertain**
  - what comes after the Space Station?
  - return to the Moon?

Alternate Visions for the Future of Space

Space Development Depends on Answers to Two Vital Questions:

Can humans "live off the land" using local resources?

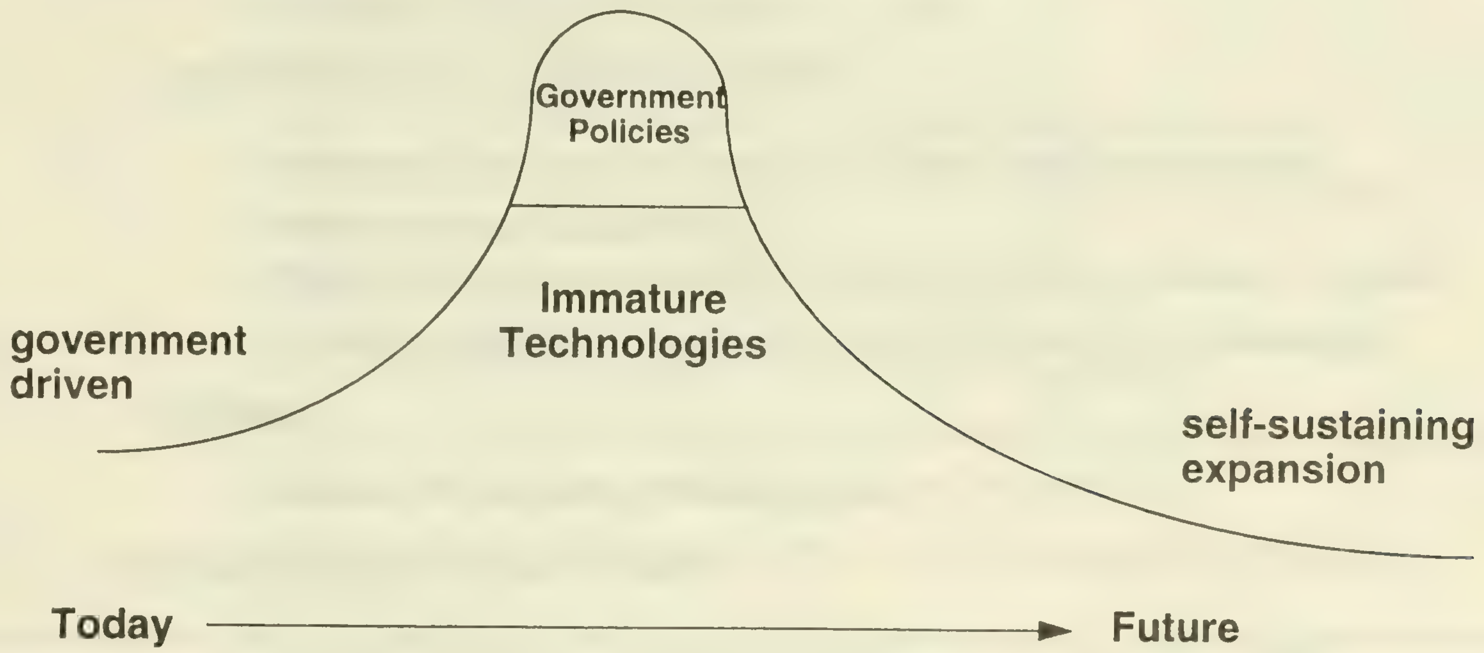
	No	Yes
Yes	Research & Tourism	Space Settlement
No	Space Science Only	Robotic labs, factories, mines

Can humans produce goods and services of value in space?

Ref. Harry L. Shipman, "Humans in Space"

Barriers to Space Development

Both Technical Advances and Policy Reforms are Needed for Human Expansion into the Solar System.



Government Policies

Immature Technologies

government driven

self-sustaining expansion

Today → Future

NSS Recommendations for Space Policy

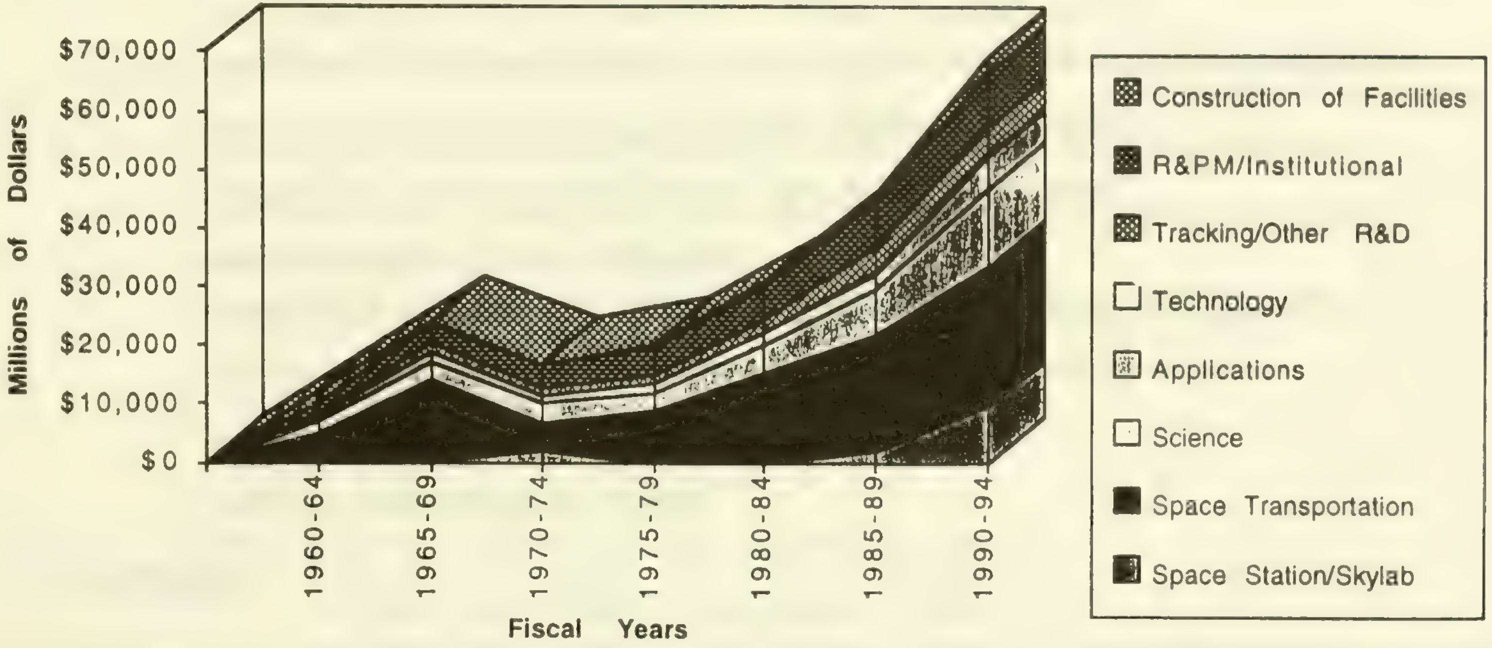
- Government Process
  - revive the National Space Council
- Taxes
  - extend infrastructure bond tax-exemptions to spaceports
  - exempt space manufactured goods from corporate income taxes, and import duties
  - establish tax-free commercial space enterprise zones
- International Agreements
  - formally reject the U.N. Moon Treaty
  - recognize private property rights in space
    - review the 1967 Outer Space Treaty
  - establish free trade regime for space goods and services

NSS Recommendations (cont.)

- NASA
  - reduce institutional costs
  - multi-year NASA authorization
  - require overdue reports on space settlement studies
  - establish voucher programs for use of aircraft, suborbital rockets, and space facilities
  - establish voucher programs for scientific data
  - full funding of X-33 effort under close oversight
  - emphasize understanding non-terrestrial resources in science and planetary missions (e.g., lunar prospector)
  - initiate modest research effort in solar power satellites and stations
  - expand research on returning to the Moon before 2005

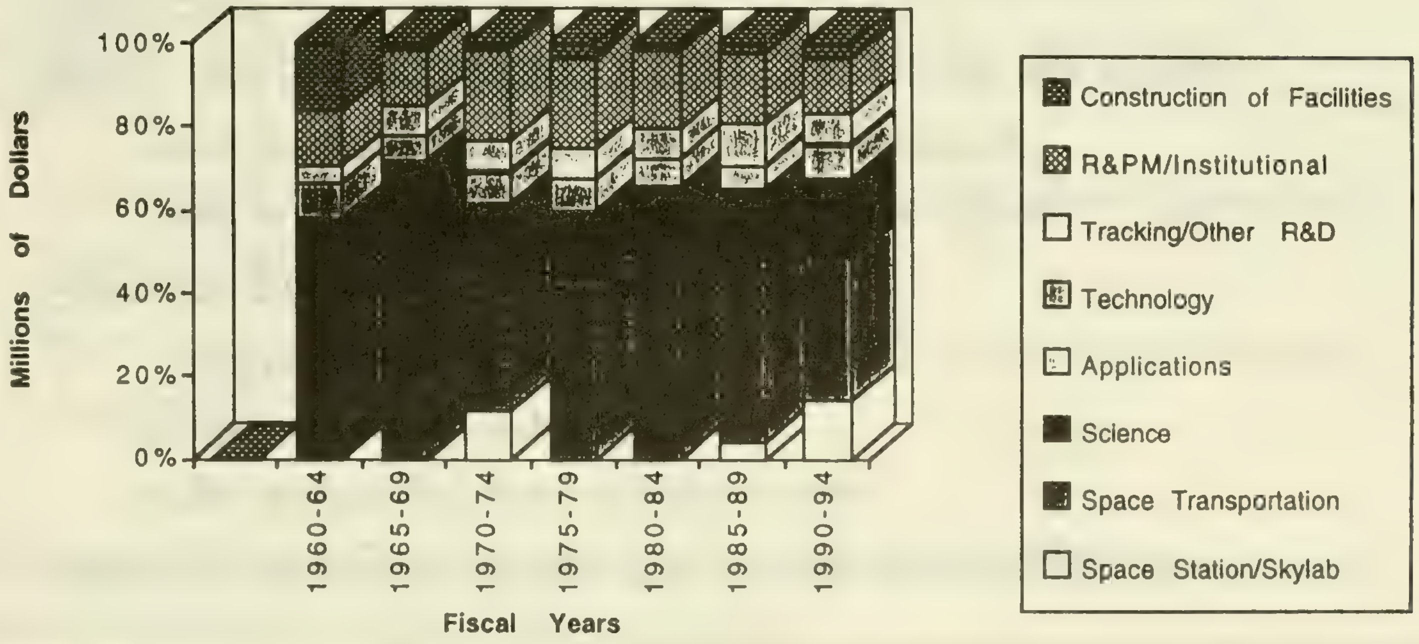
Where Have NASA Resources Gone?

Allocation of NASA Resources in New Obligational Authority



Where Have NASA Resources Gone?
(as a percent of agency efforts)

Allocation of NASA Resources in New Obligational Authority



What Should NASA Be Doing?

- NASA's budget is like the Federal budget
  - large, seemingly uncontrollable costs
  - limited discretionary ability
  - "third rail" problems
- Reform of NASA is a necessity
  - risks in being budget-driven, not vision-driven
  - need for greater flexibility and accountability
- Many NASA activities might be done by other agencies
  - NSF, NOAA, DOD
- Space science and technology is the core of NASA
  - but to what end?

Conclusion

The ultimate purpose of NASA should be to develop the tools and gain the information necessary to empower individuals to go into space for their own reasons.

- How can humans live in space using non-terrestrial resources?
- How can self-sustaining space industrialization be accomplished?

This would be a unique, vital, long-term task that could not be done by any other agency.

Appendix II

National Space Society Policy Platform

February 1995

(Attached)

NATIONAL
SPACE SOCIETY

National Space Society Policy Platform
February 1995

This document contains positions and guidelines on public policy matters affecting the goals of the National Space Society (NSS).

The vision of the National Space Society embraces the creation of a spacefaring civilization and the establishment of communities beyond the Earth. The NSS mission is to promote change in social, technical, economic, and political conditions to advance the day when people will live and work in space. We believe that the technologies and industries created on the space frontier will be of benefit to all humanity in the coming century. We believe that opening the space frontier will create new opportunities for human life, liberty and the pursuit of happiness.

Our goals include educating the public on the benefits of space development and working with allied organizations to create a supportive cultural and political environment for the exploration and settlement of space. We believe that opening the space frontier requires supportive public policies as well as technical advances.

Goals for Space Development

Spacefaring nations and organizations should conduct activities to: 1) obtain scientific, technical, and economic benefits for humanity and to improve the quality of life on Earth through space-related activities; 2) encourage private sector investment in space and related activities; 3) maintain the freedom of space for all activities that enhance the security and welfare of humanity; and 4) expand human presence in space beyond Earth orbit and establish communities throughout the solar system.

Pursuit of these goals requires several actions:

- lowering the cost of access to space
- learning how to work in space and use non-terrestrial resources
- ensuring supportive government space policies and practices
- fostering private space initiatives

Lower the Cost of Access to Space

Drastically lowering the cost of access to space is the single most important action towards accelerating space development. New initiatives should be encouraged from the civil, commercial, and military communities which require space transportation in accordance with the following principles:

- As there are many promising technical approaches to improving current and future means of space transportation, research and development activities should be diversified with varying degrees of risk (e.g., including improvements to existing vehicles as well as next generation technologies).

- Emphasis should be given to developing and operating experimental flight test vehicles, such as proposed Single-Stage-to-Orbit concepts, in order to expedite decisions on the most promising approach to improving access to space.

- The pressures of market-driven competition are likely to be the most effective tool to lowering the cost of access to space, therefore the private sector should be encouraged to take a leading role in the routine operation of space transportation systems.

- Governments should be encouraged to support research and development of space transportation technologies, to be reliable customers of commercial transportation services, and to prevent unfair trade practices through international agreements. Minimize the burden of commercial launch licensing and ensure Federal regulations preempt State and local laws.

- In order to encourage market efficiency, the U.S. Government should consider chartering private launch service brokers to consolidate purchases of space launch services and provide attractive markets for new launch systems. U.S. commercial launch firms should be allowed access to government financing (e.g., Ex-IM Bank) when competing against international suppliers with comparable supports.

- The U.S. Government should encourage efforts by private organizations, State, and local governments to establish commercial spaceports, space launch ranges, and associated facilities on public lands that are compatible with existing uses (e.g., grazing, mining, and forestry).

- Space debris may pose an increasing threat to the safe use of Earth orbit. New technologies, standards, operating practices, and incentives should be encouraged to minimize the creation of space debris without placing excessive burdens on public or private space activities.

Learn How to Work in Space and Use Non-Terrestrial Resources

Establishing communities beyond the Earth requires learning new skills and developing new technologies in order to attain self-sufficiency. Even with lower launch costs, space settlements will require using non-terrestrial materials.

- An international Space Station should be completed in order to develop and demonstrate the means for people to routinely live and work in space on a permanent basis. Space construction, servicing, and repair tasks will require crewed, robotic, and teleoperated spacecraft. Evolutionary growth of Space Station operations should encourage the creation of multiple facilities in Earth orbit for public and private interests.

- Humanity should permanently return to the Moon as soon as possible. The establishment of scientific and commercial facilities on the Moon should seek the greatest possible degree of self-sufficiency using local resources.

- The Solar System should continue to be explored with both robotic and human missions. Priority should be given to missions with potential economic as well as scientific value. This would include, for example, missions to potential resource sites on the Moon, near-Earth asteroids, and the Martian moons.

- Concepts for solar power stations on the Moon and in Earth orbit should be developed for their potential to provide energy to space facilities and the Earth. Construction and operation of satellites and facilities should emphasize economic benefits, environmental acceptability, and the use of local resources.

- The skills and technologies developed by permanent habitation of Earth orbit and the Moon should be the basis for human expeditions to Mars. The potential terraforming of Mars should be studied with the goal of sustaining large-scale permanent settlements.

Ensure Supportive Government Space Policies and Practices

Government space activities have a major impact on the technologies, systems, and resources available for space settlement. Human expansion into the solar system should be assisted but not controlled by governments. Ensuring supportive government policies and practices will require sustained attention by the space community. Near-term initiatives should include the following:

- Create a high-level focus for space policy issues in the United States through the National Space Council. The Council should be strengthened to provide timely resolution of space policy and budgetary issues affecting the national security, civil, and commercial space communities.

- Require NASA to provide reports on activities supportive of space settlements as required by Congress.

- Provide support for key enabling technologies that have limited commercial markets at present, e.g., space nuclear power, life support systems, microgravity processing, non-terrestrial materials processing, and nanotechnology.

- Create prizes for space achievements as an alternative to traditional government R&D programs. Consider privatizing portions of current NASA and Defense Department space operations.

- Create voucher programs to allow government-supported researchers greater flexibility in their use of government or private aircraft, balloons, rockets, spacecraft, and related facilities.

- Require the government to seek commercially available space goods, services, and data to the fullest extent feasible in meeting public needs. The government should avoid actions that may preclude or deter private sector space activities.

- Provide greater protection for private sector intellectual property rights in government contracts and pay appropriate royalties and licensing fees in government procurements. These steps should lower the barriers between government and commercial industry sectors and encourage investment in entrepreneurial firms serving government markets.

- Streamline and reduce U.S. and international export controls on space goods, such as commercial communication satellites.

Foster Private Space Initiatives

Human expansion into the Solar System can not be accomplished by governments alone, but requires encouraging space commerce through private sector initiatives. The commercial space sector is currently driven by information technologies such as communication satellites, remote sensing, and satellite-based navigation. Fostering future initiatives requires a supportive legal and regulatory environment including reform such as the following:

- Reject the 1979 United Nations Moon Treaty and open discussions with signatories to the 1967 Outer Space Treaty and the 1972 Liability Convention on measures to speed the commercial development of space for all parties. These should include a legal regime recognizing private property rights and allowing "land grants" to reward space settlement. As a first step, create a U.S. Federal registry for private property claims on the Moon and other bodies in the Solar System.

- Provide tax exemptions for registered commercial space enterprise zones, space-manufactured products and space-based energy sources. Extend tax-exemptions for infrastructure bonds to include spaceports and space-based facilities. Allow investment tax credits for space research and development. Clarify tax regulations on intellectual property and intangible assets for major space investments.

- Encourage space exploration missions by private industry through government purchases of useful scientific data and non-terrestrial samples.

- Amend the Warsaw Convention on Passenger Liability to include human spaceflight and clarify the 1984 U.S. Commercial Space Launch Act's authority over such activities.

- Create a U.S. "space admiralty" court as part of a Federal district court to provide a specialized forum for the development of law and precedents for space commerce and communities beyond the Earth. Encourage reciprocal efforts by other spacefaring nations.

Mr. SENSENBRENNER. Thank you, Dr. Pace. And, finally, Mr. Hayes from Cray Research.

STATEMENT OF CHARLES W. HAYES, III, NATIONAL PROGRAM MANAGER, CRAY RESEARCH, INCORPORATED, WASHINGTON, D.C.

Mr. HAYES. Good morning, Mr. Chairman. My name is Charlie Hayes. I am the National Program Manager for Cray Research, located here in Washington.

I appreciate this opportunity to speak to you today and hope my comments will be helpful.

Cray Research is a leader in high performance computing and probably the world's leader in that particular segment of the industry known as supercomputing. We are headquartered in Eagan, Minnesota, a suburb of Minneapolis/St. Paul.

We have major operations in the State of Wisconsin, in which all of our engineering and manufacturing for our supercomputers is conducted. We have about five thousand employees. And, 1995 revenues totalled 921 million; after tax, profits about 55 million.

The business of Cray Research is particularly important to the federal government. And, the federal government is particularly important to Cray Research.

The government is by far our largest customer and always has been. Only the Department of Defense exceeds the business over NASA for Cray Research.

We have computers installed at seven of the nine major NASA facilities. These computers are involved primarily for scientific purposes in the area of modeling and simulation and in such applications as computational fluid dynamics to augment the work done in the wind tunnels that Dr. Grey talked about earlier today; global weather forecasting over aerospace sciences; satellite data analysis; and, even shuttle flight planning services.

In fact, the supercomputers from Cray Research touch just about every program within NASA. And, we believe they help make the United States the world's leader in aerospace technology.

Now, to the real business at hand. The United States is really locked in a competitive world struggle for dominance in the aerospace industry.

Again, as Dr. Grey pointed out, this industry in the United States generates right now a positive 25 billion dollars in trade surplus. Unfortunately, the competition from around the world is growing rapidly.

The ability for the United States to continue to compete and lead in this area is dependent upon the cooperation of government and industry, particularly NASA and industry, to help develop the fundamental technologies that will maintain our position as the world leader in the future.

We believe that the supercomputers will provide the designs and the technology to help further this technology race. It is widely accepted that computer simulation dramatically reduces the time to market and, therefore, the cost of production.

This is true not only in the aerospace industry but other industries as well. An example we love to use is that in the automotive industry.

Ten years ago, it took 10 years to create a new automobile from a white sheet of paper. Today, that is being done in less than three years. Within the next two years, it will be done in two years.

This is solely because of the use of high performance computers in the design of these devices. This is also true, of course, in the aerospace industry.

To understand NASA's role with the aerospace industry in this partnership to provide the technology for the future, you must understand that there are three primary levels of high performance computing within NASA. The first is NASA's participation in the government-wide HPCC program, the high performance computing and communications program.

This is a computer science R&D program. It is run by the Aeronautics Division within NASA, although it touches other divisions in NASA as well.

Its objective is to develop new hardware and software technologies that someday will provide the performance increases to NASA researchers necessary to maintain our competitive posture. We are proud to be a part of this program, of course.

As a matter of fact, at the Jet Propulsion Laboratory, we have an installation. One of the first of our large, new, massively parallel computers is installed there. It is being used under a funding—a cost-shared program with Cray Research under HPCC for the development of computer science technology.

I think if you would talk with the people at JPL, you will recognize that this installation has been an amazing success. They have developed technology which genuinely is going to help NASA researchers and scientists around the world, particularly in the areas of satellite data transmission and understanding.

The second major phase is the numerical aerodynamic simulation program, the NAS program, located at Ames. This is a separately funded program in aeronautics to provide state-of-the-art computers for the development of techniques and tools for the design of aircraft, aircraft systems, flight systems. Its purpose is, again, to maintain this country's leadership position in the aerosciences. The important point I would like to make is that the high performance computing program within NASA and the NAS program are separately funded programs.

Cray is also a supplier under the NAS program. And, we hope that the results coming out of this will, again, lead to our future competitiveness. These two programs are separately funded within NASA.

The final and third most important program is the program surrounding the central computation facilities within NASA. Unfortunately, these are not separately funded programs but are funded by the individual aeronautic programs. And, they are not keeping pace with today's technology.

NASA management has stated here that by the year 2015 we need nine orders of magnitude greater speeds in our computers. The only way that is going to happen is by continued support by the federal government in the research of these computational tools.

I know my time is short, so I will end here by saying that we hope this Committee will support the continued funding of the supercomputer facilities within NASA. We support it. And, we believe that it will be the primary contributor to our competitiveness in the future.

Thank you very much. And, I will be happy to answer questions.

[The prepared statement of Charles W. Hayes, III follows.]

Statement of Charles W. Hayes, III
National Program Manager

Cray Research, Inc.

Before the

Subcommittee on Space and Aeronautics

Science Committee

United States House of Representatives

March 16, 1995

Testimony Before the Space and Aeronautics Subcommittee
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Mr. Chairman, thank you and good afternoon. I am Charles Hayes, National Program Manager at Cray Research, Inc., responsible for management of our company's activities at NASA Headquarters. I appreciate this opportunity to speak to you today and hope that my comments are helpful.

As you may know, Cray Research is a leader in high performance computing (HPC) and the world's leader in the engineering, manufacture, sale, and service of that class of high performance scientific computers and software, known as supercomputers. Our company is headquartered in Eagan, Minnesota, a suburb of Minneapolis and St. Paul. In addition to our presence in Minnesota, we have a major operation in Chippewa Falls, Wisconsin, where all of our supercomputer R&D, engineering and manufacturing is performed. We have about 5000 employees, half of whom are located in Wisconsin. Calendar year 1995 revenues were approximately $921 million with after tax earnings in excess of $55 million.

Over the last twenty years, our business with the federal government has been by far our largest and most important segment. Within this segment only the Department of Defense exceeds NASA in volume. Clearly, NASA has been and will continue to be a valued customer.

We currently have our supercomputers installed at seven of the nine major NASA Centers. These supercomputers are involved, for the most part, in modeling and simulation applications, to include: computational fluid dynamics for airframe and engine design, global weather forecasting, satellite data analysis, and shuttle flight planning. In short, our supercomputers touch just about every NASA program at all NASA centers and help, we believe, make the U.S. the world's leader in aerospace technology.

I would like to comment briefly on the significant contributions made by NASA and its contractors, even in these times of real budget constraints, on the development of technologies which have bettered the quality of all our lives. Many advances in electronics, materials, medicine, etc. that benefit us all can be traced directly to research performed for the space program.

Now, to the business at hand. The U.S. aeronautics industry is locked in a global struggle with foreign competition for world dominance in military and commercial aviation. Despite our current $25 billion positive surplus in commercial aircraft foreign trade, foreign competition has made dramatic strides in its ability to compete with us. Our ability to continue to lead this competitive race will depend in large measure on the continued cooperation between government and industry.

The aeronautics research, jointly performed by the U.S. aerospace industry and NASA, provides the foundation of technology for future commercial aircraft products. We believe the use of supercomputers, to create and test the designs, will play an even greater role in our future success. It is now widely accepted that computer simulation dramatically reduces time to market and, therefore, cost of product development.

To understand NASA's part of this partnership with industry, I wish to review the three levels of high performance computing in NASA. The first is NASA participation in the government-wide HPCC initiative. This program is funded through the Aeronautics division but effects other divisions in NASA as well. HPCC is the computer science component of NASA's HPC effort. Its objective is to develop and test new computer hardware and software technologies that someday will provide the performance increases that the aeronautics researchers estimate will be necessary to remain internationally competitive. Cray Research is proud to be a part of NASA's HPCC program. One of the first locations of our new T3D massively parallel computer system was installed at JPL in a joint cost-shared project to push the frontiers of computer science. I am proud to report that this installation by all measures has been a major success for both NASA/JPL and Cray Research.

The second component of NASA's HPC activity is the Numerical Aerodynamic Simulation (NAS) Program located at the Ames Research Center. This program is separately funded by NASA in Aeronautics to provide state-of-the-art production computation capability for NASA aeronautics researchers and the U.S. aerospace industry, working on selected leading-edge technologies of national importance. Its purpose is to maintain our country's world-wide leadership position in the aerosciences. The important point is that this program, like HPCC, is funded as a separate program for its users, both in NASA and the U.S. aerospace industry. Cray Research is also proud to be the current primary NAS supercomputer vendor and believes that, like the HPCC Program, the NAS Program is critical to this Nation's continued international competitiveness.

I believe it important to reiterate once again that these first two programs are individually budgeted in Aeronautics and are essential to the long range maintenance of the U.S. $25 Billion commercial aircraft trade surplus.

The third component of the NASA HPC environment is the Central Computation Facilities (CCF's) at the various centers. Traditionally, the CCF's have been the primary source of supercomputer time for the various space and aeronautics programs at the centers. Each CCF has its own complement of equipment to serve its own local NASA research community. Unfortunately, there has not been any significant new equipment budgeted for the CCF's.

The Agency has stated that computer speeds are off by nine orders of magnitude from what it wants by the year 2015. This is a clear indication of the importance of high performance computing to the future of NASA. As the complexity of aerospace technology grows, so will the demand for supercomputers and their applications. Although these applications will continue to evolve, the supercomputer will continue to be a major element in the development of operational aerospace systems.

These supercomputer resources must be maintained at the state-of-the-art level for NASA to attain its many technological goals and objectives for the future. We believe that funding for supercomputing technology is a cost effective way to help the NASA engineers fulfill their missions. We look forward to working with Congress and NASA to develop ideas and methods to address the many issues facing the age and their research centers to ensure a balanced approach that will help save money and maintain their supercomputer capabilities. We support an ongoing, funded program to modernize the HPC assets at NASA.

I thank you very much for your time and would be pleased to answer any questions you might have.

Mr. SENSENBRENNER. Thank you, Mr. Hayes. The gentleman from Kansas—well, we might as well have a 15 minute recess to go and vote.

So, if you all would be patient while we go over and do the job that we were elected to, we will be back as soon as possible.

[Whereupon, a recess is taken at 10:25 a.m., to reconvene at 10:38 a.m., this same date.]

Mr. SENSENBRENNER. The Subcommittee will be in order.

And, the Chair recognizes the gentleman from Kansas, Mr. Tiahrt.

Mr. TIAHRT. Thank you, Mr. Chairman. Mr. Spitzer, it's nice to see you again.

I know you have spent some time in the air capital of the world, Wichita, Kansas.

[Laughter.]

Mr. TIAHRT. And, of course, that's my district. But, I would like you to address what you think the core differences between—what you think are the core differences between the aerospace industry research agenda and the agenda of NASA as far as research is concerned; and, also, why do you think industry—why doesn't industry pay for this?

Mr. SPITZER. Well, let me say that what NASA—where NASA's role fits and the industry role fits is sort of along a continuum of R&D work. And, NASA looks at fundamental technologies across the broad spectrum that's useful for the entire industry.

So, in a sense, in a national sense, I think that NASA provides a way to get technologies that's not just for one company but for the industry to use. For example, NASA has developed a lot of the structural modeling tools, a lot of the national facility work. And, that's something that we wouldn't be able to do.

Even in their programs now, to develop such things as an interest in the technologies for the supersonic program, they are looking at the pre-competitive technologies. They are not really trying to build an airplane but trying to see if it's feasible.

Where the industry picks up is to take that technology, once we see that it has a chance to work or we can use it, and to apply it. And, we spend our money in the application oriented activities and try to bring it to a product base so we can use it.

So, the line of demarkation is NASA is in a pre-competitive role to develop technologies and we are in the role of doing that. Quite frankly, industry wouldn't be able to afford the wide spectrum of technologies that NASA works on by any one company and so we probably wouldn't do all those things and we would fall behind.

And, our competition overseas is doing that wide spectrum. So, we would have that kind of competitive disadvantage.

But, also, you know, the idea that NASA is an innovator and brings on people with ideas across this broad spectrum is important. And, companies almost always like to rifle shot on what the answer is after they know where they are at.

And, innovation with the kind of climate that NASA provides in aeronautics is a very important factor to do that. So, there is a role there that I don't think industry can fulfill.

Mr. TIAHRT. So, the aerospace industry sort of picks up and applies the basic research that has been done by them?

Mr. SPITZER. That's correct.

Mr. TIAHRT. How much in an international basis—I know air bus has been a big competitor, what do the—in their governmental conglomerate, how much do they provide as far as basic and applied research to air bus?

Mr. SPITZER. Well, we don't have access to all air bus financial records in knowing that. But, we know that they have had support by their governments in terms of the R&D work.

They do not have a NASA in Europe and look enviously at the United States for having that kind of consolidated research. Instead, they pick it up as an amalgam or research in Germany and France and The Netherlands and England and from the different places in Europe.

But, we know that they use that. And, we also know they use NASA data if they can get on it.

In fact, in the supersonic program, we have some slow-down restrictions on the promulgation of the NASA program so it doesn't just float across the pond in a short time. So, they do have that program.

They also have a lot of government support. And, they have built a very brand new wind tunnel facility in Cologne, Germany as a consortium. And, they have shown support for their industry big time.

Mr. TIAHRT. Dr. Grey, I know that we have aeronautical initiatives that are handled by NASA and by the Department of Defense and by the FAA. Do you think that we do an effective and efficient job of coordinating our efforts? Or, do you think we could have a better job of delivering basic research by some other structure in place?

Mr. GREY. There are several structures in place for cooperation. It's like mother love. You can always improve the coordination between the three agencies, particularly with regard to some of the technologies that NASA develops in bringing them into the certification process, into the FAA process, for example. There are probably improvements that could be made.

But, the current process seems to work reasonably well. There have been coordinating committees between certainly the DOD and NASA for a long time. And, that has worked reasonably well.

Unfortunately, with the downsizing of the Department of Defense, much of the research that formerly was done in Defense laboratories has now been, you know, cut back significantly, leaving NASA as the primary source for aeronautical research in the country today.

Incidentally, I have an answer to your question to Mr. Spitzer. It's in our wind tunnel report.

And, that is a GAO report indicated that the French, German and British governments invested 13 and a half billion dollars in direct support of Airbus products. By August of 1993, the amount repaid was only three and a half billion. So, that's from a GAO report.

Mr. TIAHRT. Thank you, Dr. Grey.

Mr. SENSENBRENNER. Time of the gentleman has expired. The gentleman from California, Mr. Calvert.

Mr. CALVERT. Thank you, Mr. Chairman. I have some questions for Mr. Spitzer regarding the wind tunnels also.

And, I unfortunately was not able to listen to all of your testimony. But, as we understand it, a comprehensive study of technical, financial and other issues related to the development of the national wind tunnel complex is now underway utilizing funding provided to NASA in FY 1994.

When will this study be completed? What information will we gain from the study? And, is it sufficient funding available to complete the study?

Mr. SPITZER. Let me try to answer that. There is a study activity underway with the team of people from industry—actually from a number of industries and NASA in Cleveland, Ohio. And, that team is studying the technical requirements for a national wind tunnel complex, both in a lower speed tunnel and a transonic wind tunnel to get the technical requirements solidified. Even the Department of Defense is contributing their technical inputs to this tunnel study.

So, the first phase was to identify the technical requirements and make sure that we weren't overdoing the tunnels but still meeting a national consensus of need.

The next phases have to do with understanding what the preliminary design approach would be to those tunnels and what it would mean to understanding the site requirements, basically how much concrete and steel and everything you need to do the job, and to get a more accurate understanding of the cost estimate that those tunnels would have. And, that study phase is underway.

And, it has some various stages of completion, stretching out into early 1996, which we will then have a basically preliminary feasibility complete package on what the tunnels would be before you would start any construction.

Mr. CALVERT. What would be the critical path or future support for advanced facilities such as these by the Department of Defense?

What thresholds of performance, design or any other feature would be indicative of participation or non-participation by the Pentagon as far as wind tunnels are concerned?

Mr. SPITZER. Well, what we look at in this tunnel facility is a need to build something that has a properly managed construction project with all the attendant managerial activities that goes with that and using experienced industry people—and I'm not talking about airplane people but I'm talking construction industry people that would really understand how to manage it.

The funding source is really one of the key issues here. There is money being talked about as an add-on for the NASA budgets to pay for the tunnels.

But, the tunnel costs are sufficiently high that it needs a broader base of financial support. And, I'm not aware at this point whether DOD has offered to put anything in the pot to pay for some aspect of the tunnel.

Mr. CALVERT. Well, do you think that NASA can develop a cost-sharing approach with both the state and local governments on the location that you choose along with industry to build and operate a new wind tunnel complex where everybody would get together and work out some kind of arrangement?

Mr. SPITZER. We are trying a novel management approach to the tunnel project. And, industry has been polled.

And, there will be some industry contribution to the tunnel. And, we've had—actually a lot of people come around from various state and local people asking what they can do to have the tunnel in their area and to the place where I think there is a lot of state and local interest in placing tunnels in various sites across the country.

So, it will be a joint venture type of program before it's over with. And, I think it can be done.

Mr. CALVERT. Thank you. And, thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentleman from Florida, Mr. Weldon.

Mr. WELDON. I have a few questions for Mr. Spitzer. You mentioned in your testimony that industry is currently going overseas to utilize some overseas facilities.

Mr. SPITZER. Yes.

Mr. WELDON. Can you tell me where those facilities are?

Mr. SPITZER. We tested in the British Research Establishment facilities in England. We have actually tested in other tunnels.

We have gone to Esage [phonetic] facilities in Moscow. We have tested also in the United States—so I don't want to take away from that—at NASA tunnels.

Mr. WELDON. Are those overseas tunnels more sophisticated or advanced than the current tunnels we have right now?

Mr. SPITZER. The low speed tunnel in England is a very advanced tunnel and not the capability of what we are talking about for the new tunnels, but it is a good tunnel. The Russian tunnels are more comparable with what is available we found in NASA.

So, I wouldn't say they are as advanced as where we are today. And, the tunnel coming on line in Cologne, Germany that we've yet to test in, because it's just on line this year, that tunnel is a very advanced tunnel that is coming on line, owned by the German, French and British interests.

Mr. WELDON. And, was that tunnel built with European tax dollars?

Mr. SPITZER. I personally haven't done the investigation. It's my understanding that it had government support, since the industries that are represented are totally government owned and operated and they've had government money.

Mr. WELDON. Could you elaborate a little bit more on this aspect of all this? This is obviously an area of interest to many of us by the nature of the questioning.

As I understand it, the aerospace market is over a trillion dollars—I believe one of you mentioned that in your testimony—in the upcoming early half of the next century. Why is it that we need taxpayer support for this?

If the wind tunnel is so crucial for us to maintain the lead and this market is so tremendous when you compare the cost of the wind tunnel versus the market, it would at least appear to me on first analysis to be something that industry would be willing to support.

Mr. SPITZER. We did make an attempt to look at that several years ago as a privately financed, single company activity. And, for a single company for the utilization of the facility and how we use it, it was not an economically viable single activity.

A facility like that needs to be a national facility that everyone uses so that it can be productive and used, literally two shifts a day and around the clock as a national productive facility. So, it didn't pass the test for a single company to invest in a single activity.

And, NASA has a role of providing tunnels and facilities for the nation. It's a good place to go and work that out in a joint venture activity. And, that's where we are today.

Mr. WELDON. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentleman from Tennessee, Mr. Hilleary.

Mr. HILLEARY. Thank you, Mr. Chairman. Of course, we have been kind of up and down on the funding of this wind tunnel.

And, I would just like to ask Dr. Grey. Assuming we can't get funding this year for, say, construction of a new wind tunnel facility, I want to ask you specifically how imperative it—I think it's absolutely imperative but what you think with regard to the development funding, continued funding for the project itself, getting it developed, fully developed?

And, Mr. Spitzer, I would like to ask you. You know, what's going to happen here? I mean, one of you testified that there is a 25 billion trade surplus. And, that's got to equate to hundreds of thousands of jobs directly and indirectly.

And, we are talking about if that continues to dissipate, I mean, are we not going to actually lose a tremendous amount of tax revenue?

And, wouldn't it—I mean, how can we afford not to build the wind tunnel, Mr. Spitzer? But, Dr. Grey, please go ahead first.

Mr. GREY. Your question regarding how imperative it is to go ahead with the tunnel, I think, is a very good point. The European transonic wind tunnel, the one that was just mentioned earlier, was totally financed by the governments of The Netherlands, England and Germany. They are covering all operating cost shortfalls until 1997.

So, they obviously consider this as a major national, in fact, international concern in Europe.

The job loss that would occur in this country, I think perhaps Mr. Spitzer could address better than I could. But, we have in our paper—in our testimony, for example, we've got some numbers regarding the jobs that are created by the construction of the tunnel and by a one percent improvement in market share.

And, it's significant, both in terms of tax revenues to this country that the manufacturers would pay and also in terms of the jobs that would otherwise be lost that would be created. So, these are significant numbers.

And, I think it's necessary for us to find a mechanism to build this tunnel somehow. If it cannot be done on budget, some off budget method of doing it has got to be developed.

And, I think some of the consortium people are looking into, let's call them, innovative mechanisms for financing the tunnel.

But, the direct answer to your question is, yes, it's imperative. And, yes, as soon as we can get them built the better.

Mr. HILLEARY. Thank you.

Mr. SPITZER. I would just like to respond to your question this way. I don't think the American industry is willingly trying to fall behind in the competitive world we face in terms of commercial airplanes. Both Boeing and Douglas are very active in pursuing the marketplace.

But, you are right in one sense, and that is the world has seen this kind of capability and is very envious of us and want it very badly. And, we are seeing European competition coming on big time.

And, there's potential other competitors out there as the future develops. And, they see this market.

And, the work we are doing both in tunnels and in the basic aeronautics R&D that is happening is an attempt to keep us on the forefront of the marketplace. And, we at our own company at Boeing are striving right now to make sure we are running as tight a ship as we possibly can to deliver quality and value to our customers.

So, we are all very, very competitive at this point in time. And, I think there is a place for the national facilities and a place for NASA as a way to provide us some of that front-end technical help.

Mr. HILLEARY. I guess my point was that unlike so many other big ticket items, it seems like that in this particular case I don't see how we can afford not to build this if you are talking about taking 100 thousand jobs and moving them to Europe, you know, as it seems to be the trend. Even from, you know, a future tax revenue standpoint, I don't see how we could afford not to do it. But, thank you for your answer. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentlewoman from Texas, Ms. Jackson Lee.

Ms. LEE. Mr. Chairman, thank you. And, I would like to offer a few remarks for an opening statement. I would like to be recognized accordingly.

Mr. Chairman, first of all, let me say to the panels and those who have preceded my coming in of my great interest in this area. Either fortunately or unfortunately, we have overlapping responsibilities which included a markup in Judiciary Committee this morning.

But, I did want to note the significance of these hearings as well as the significance, I think, of the continuation of an effective and efficient NASA. I had the good pleasure and opportunity to visit with our most recent space team that included Dr. Bernard Harris and several others and, as well, to see some of the intricacies, if you will, of the most recent or the preceding space flight where they made contact with MIR.

It is important, I think, that we engender information that comes from our outside community, if you will, to ensure that NASA can move effectively into the 21st century.

I note the previous witnesses talked about restructuring, raised issues about the myriad of contractors that seem to be supervising so many different centers, certainly talked about the opportunities for the technology that is developed through NASA to be translated into business opportunities. And, certainly, as I understand is being presently discussed, this whole concept of the wind tunnel which, as we speak and we are discussing the rescissions bill, I will say to you that it seemed that my colleagues find themselves most attracted to taking dollars away from the NASA program as the most expendable of what we have.

And, I would argue differently to a certain extent. I would hope that we wouldn't even be moving forward on a rescissions bill, but particularly I think you have offered one very positive suggestion to what NASA can actually be effectively and, as well, the vitality that we should look to or expect from NASA so that it can be contributing to some of the many focuses that we would like to have our science community focus on.

I wanted to, in concluding these basic opening remarks, simply focus on a question that I think was being discussed or pointed out here amongst this present panel. And, that deals with the wind tunnel studies and analysis, if I'm correct.

And, if there's any member on the panel right now that can respond to me—and I apologize if you've already given the virtues and the negatives of this, but I'm going to ask a very simple question. Why wind tunnel technology and research?

If someone would be able to answer that question, I'm asking it as sort of a—in a manner that would hopefully solicit the pros and cons.

Mr. SPITZER. Yes.

Ms. LEE. Mr. Spitzer.

Mr. SPITZER. Please, thank you. Let me answer this this way. When we design an airplane, we try to do it by finding the best way to handle the operating cruise points on the aircraft and do it by computational fluid dynamics and all the latest tools.

But, that activity can only get at the few point design places in the airplane. When you start looking at the full flight envelope, we have to address off speed conditions, separated flow, anomalous behavior points.

Then, the place to get that data economically with the right kind of technical approach, including flow separation, is in the wind tunnel. Our progress in CFD has not covered the entire flight envelope.

So, the companion to using computational methods with wind tunnel simulation is necessary to do the design. In order to get that design up to the place you need to be, you need a tunnel that emulates full scale flight.

And, as we go to bigger airplanes and more sophisticated airfoils, we need more modern facilities to do that. And, that's really the basis behind looking at newer generation wind tunnels for the nation, is to have that balanced capability that brings the tunnels along with the computational efforts to keep us up on the forefront of what we are doing.

In order to do that, I must point out that you need the balance. It's just not tunnels alone and no aeronautics.

You don't get the whole answer. You have to have the balance in the total program. And, that's what we are trying to say, you need both of those.

Ms. LEE. Let me thank you, Mr. Spitzer.

Mr. SENSENBRENNER. The time of the gentlewoman is expired.

Ms. LEE. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The gentleman from Texas, Mr. Stockman.

Mr. STOCKMAN. Thank you. Mr. Hayes, I have a question regarding computing.

And, by the way, I have a quick story that we are working in one of the large oil corporations. And, one of your computers were there. And, it has that—it looks like a seat around it. And, I found out that's not a seat, you shouldn't sit there. It would be millions of dollars' worth of damage, I guess, if you sit too hard.

[Laughter.]

Mr. STOCKMAN. One the questions I have for you. The DOD currently is talking about compressing all the computer operations into a central configuration. Could you describe to me what they are doing at the DOD? And, is it applicable to NASA?

Mr. HAYES. Well, several years ago, the Department of Defense realized that their inventory of high performance computing primarily at the science and technology laboratories was getting old. As a result, they created the DOD HPC modernization program, which was initially authorized in 1993 and now has been cooking a couple of years.

It is a program that has five more years to run. There are a number of components to this program.

One of the components is called the "Major Shared Resource Centers." This is a component in which the Department of Defense is creating not one but four major centers around the country, connected to each other with high speed communications lines into which many of the S&T researchers will access for their work.

These are large centers similar to the NSF style supercomputer facilities to provide a full spectrum of high performance computing capability for the researchers. There are other components to this program as well.

But, yes, you are right. They do have a program of large-scaled consolidation but not in a single facility but rather in four separate facilities around the country interconnected by communication lines.

Mr. STOCKMAN. Do you feel NASA could benefit from doing a similar approach?

Mr. HAYES. Well, let me say that we are all awaiting Mr. Goldin's review on May 17th in which he will discuss the restructuring of NASA. Before I would comment whether or not a large-scaled consolidation program should take place in NASA, I think it's fair for us to look at what Mr. Goldin has in mind for this.

Mr. STOCKMAN. But, you don't work for Mr. Goldin, do you?

Mr. HAYES. No, I don't. No, sir.

Mr. STOCKMAN. What's your opinion?

Mr. HAYES. We believe that the communications technology has reached a point where certain levels of consolidation are possible. However, we also believe that there are many applications, particularly in NASA, that dictate dedicated or local access systems.

So, I am not of a mind to absolutely advocate full scale consolidation of the high performance computing facilities in NASA.

Mr. STOCKMAN. So I understand you are saying that it's good for the DOD not but NASA?

Mr. HAYES. No. I told—what I indicated was that within DOD one of the components was a shared component. They also happen to have a component which they refer to as distributed computing that also provides separate individual facilities around the country, particularly for those applications that cannot tolerate long communication delays.

Mr. STOCKMAN. If we contracted out to a separate vendor such as your wonderful company, would we save the taxpayers any money, do you think?

Mr. HAYES. Well, we believe that the use of high performance computers, particularly modern, current generation, high performance computers will genuinely save NASA money. There are many places within NASA in which there are computers in use, high performance computers in use, that are several generations old.

And, these are expensive to operate. Return on investment for these older computers is not what they could be today. So, we would advocate a modernization program within NASA, yes.

Mr. STOCKMAN. Well, I guess what I'm saying is if we contract out at an hourly rate, you fellows could update it quicker without going through the bureaucracy.

Mr. HAYES. That is an alternative that I believe Mr. Goldin is reviewing right now as we speak.

Mr. STOCKMAN. Okay. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The time of the gentleman has expired.

The gentlewoman from California, Ms. Harman.

Ms. HARMAN. No, thank you, Mr. Chairman. I don't have any questions.

Mr. SENSENBRENNER. That concludes the questions for this panel. We would like to thank you for coming up here.

Again, members will be allowed to ask written questions within a week. And, we would appreciate your response within a week to 10 days after receiving them. So, thank you for coming.

The fifth panel will be on the subject of Mission to Planet Earth. The witnesses will be Professor Jim Anderson of the Departments of Chemistry and of Earth and Planetary Sciences at Harvard; Dr. Eric Barron, Director of the Earth Systems Science Center at Pennsylvania State University; Dr. Arthur Charo, Senior Analyst at the International Security and Space Program in Washington; Mr. Jack L. Brock, Jr., Director of Information Resource Management/National Security and International Affairs at the General Accounting Office; and, if he comes—and we are running early—Dr. Edward Teller of the Lawrence Livermore National Laboratory in Livermore, California.

I think because Dr. Teller is not here, we will begin with Professor Anderson once he is seated and ready to go. Is Professor Anderson here? Okay. Take your time.

Okay, Dr. Anderson.

STATEMENT OF JAMES G. ANDERSON, PROFESSOR, DEPARTMENT OF CHEMISTRY AND DEPARTMENT OF EARTH AND PLANETARY SCIENCES, HARVARD UNIVERSITY, CAMBRIDGE, MASSACHUSETTS.

Mr. ANDERSON. Thank you, Mr. Chairman. I have been asked to appear before this panel as a non-agency witness.

I have been asked to consider the NASA mission to planet earth. And, I have submitted testimony in written form that I submit for the record.

In that capacity as a non-agency witness, I would like to ask: Why is it in the national interest that we study the earth? Part of that question revolves around whether any scientific inquiry has ever fundamentally changed our picture of the way the earth behaves.

Also, in that question is the issue of whether there is a link between economic competitiveness and studies of the Planet Earth. And, finally, there is the question of how the technical wherewithal to study the earth affects the intrinsic vitality of the country's technical infrastructure.

I think these questions deserve careful attention. So, I would like to turn to them in order.

Question One is: have we ever executed scientific experiments that change our picture of the way the earth behaves?

I would like to turn first to the 1950s when the world began to study, particularly through the International Geophysical Year, the stratospheric ozone distribution over the earth.

In the late 1970s, a discovery was made over the Antarctic by the British Antarctic Survey that there was an episodic drop in ozone as the spring season set in over the Antarctic. In 1985, those results were published in "Nature."

It set off a reaction both in the scientific community as well as the public policy community. I would like to note that in the following year, 1986, NASA staged a mission by sending the high altitude U-2, which is now called the ER-2, into the region over the Antarctic.

Exhibit A here on the left captures the discoveries made in that NASA mission. The first discovery was that there is dramatic containment over the Antarctic provided by the wind field. This containment isolates the region over the Antarctic from the rest of the stratosphere.

The second discovery was that there is a clear evolution in the anti-correlation between ozone and chlorine, specifically the form of chlorine that attacks ozone directly, namely chlorine monoxide. So, a comparison between the two panels at the top indicates, first, the initial condition in Panel A as the sun emerges over the horizon over the Antarctic showing ozone emerging from the polar night unaffected. The very high levels of reactive chlorine inside that containment vessel are displayed.

Three weeks later, there is a dramatic drop in ozone. There is a clear anti-correlation in all volume elements relating the presence of high ClO to the presence of low ozone.

The third discovery involves the determination of the rate at which that ozone disappears. Unequivocally and clearly this mission demonstrated that had CFCs not been added, ozone would not be lost over the Antarctic.

Question Two. What are the links between economic competitiveness and these earth studies?

Here I turn to commercial aircraft, the subject of the previous panel. Commercial aircraft constitute an international market, as we've heard, of 50 billion dollars or so per year.

And, high speed civil transport is a key component in the battle for leadership. The question here is: do the nitrogen oxides, water and particulates emitted by this plane affect the ozone distribution of the stratosphere?

The Senate hearings of the 1970s concluded yes. With the best information available then, there was a link between the release of NO_X and the destruction of ozone.

Well, NASA has put in place a research program to investigate this question, to investigate the fundamental hypothesis. And, Exhibit B, on the right, is this second demonstration.

The picture in the 1970s was that increasing ozone losses are related to increasing NO_X. Well, the first discovery was in 1992 when the NASA ER-2 found that small aerosols convert these reactive nitrogen compounds back to the less reactive forms, the forms that do not attack ozone. This was the first crack in this fundamental hypothesis.

In 1993, another set of NASA ER-2 flights demonstrated that radicals containing hydrogen and chlorine dominate the destruction of ozone in the lower stratosphere and not NO_X. And, more than that, the linking reactions between hydrogen and nitrogen and between chlorine and nitrogen says that if you add NO_X to the lower stratosphere you reduce the rate of ozone loss.

So, this opens up the very clear possibility of developing an aircraft if similar data are obtained in the region at higher altitudes where most ozone exists and the stratosphere turns out to reflect this behavior, allowing the development of a U.S. High Speed Civil Transport in a coordinated effort between the scientific results and the aircraft design.

And, if you are waving that gavel, I submit my time is up. Thank you.

[The prepared statement of James Anderson follows.]

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Mr. Chairman and Members of the Committee:

I have been asked to testify, as a non-Agency witness, on the budget deliberations as part of a panel considering the NASA *Mission to Planet Earth*. In this capacity, I would first pose the question: **Why is it in the national interest that we have a mission to study this planet?** This question deserves critical appraisal. Have we learned from scientific inquiry any facts that constitute an unequivocal reordering of our thinking about how this planet behaves? Are there clear links between the discoveries associated with Earth studies and our economic competitiveness? What is the relationship between the technology required to investigate the dynamics, radiation and chemistry of the earth's atmosphere and oceans and the technical vitality of the United States? We briefly consider these questions.

Has scientific inquiry ever fundamentally reordered our thinking about this planet? *The discovery and diagnosis of the Antarctic Ozone Hole was a major, unanticipated surprise for scientists and for the public policy structure.*

In world-wide studies extending back to the 1950s, the amount of ozone over the Antarctic was tracked each year through its seasonal cycle. In the late 1970s, an anomalous deficit emerged in the total ozone amount in the late winter observations. In 1985, the British Antarctic Survey reported for the first time in the scientific literature that dramatic losses were occurring in the ozone concentration over Halley Bay and that the degree of ozone loss was worsening as the decade progressed. Theories for the cause of this unprecedented loss blossomed. Explanations were offered, ranging from simple redistribution by atmospheric motion, to chemical reactions initiated by magnetic field focusing of solar electrons and protons. These theories were put forward by serious scientific research groups in an international effort to diagnose the cause of this unexpected development. A number of expeditions were planned to gather more complete information. In 1986, NASA, in cooperation with other agencies, planned an airborne expedition using the ER-2 aircraft to penetrate into the region of the stratosphere where ozone was disappearing. The key results are shown in figure 1.

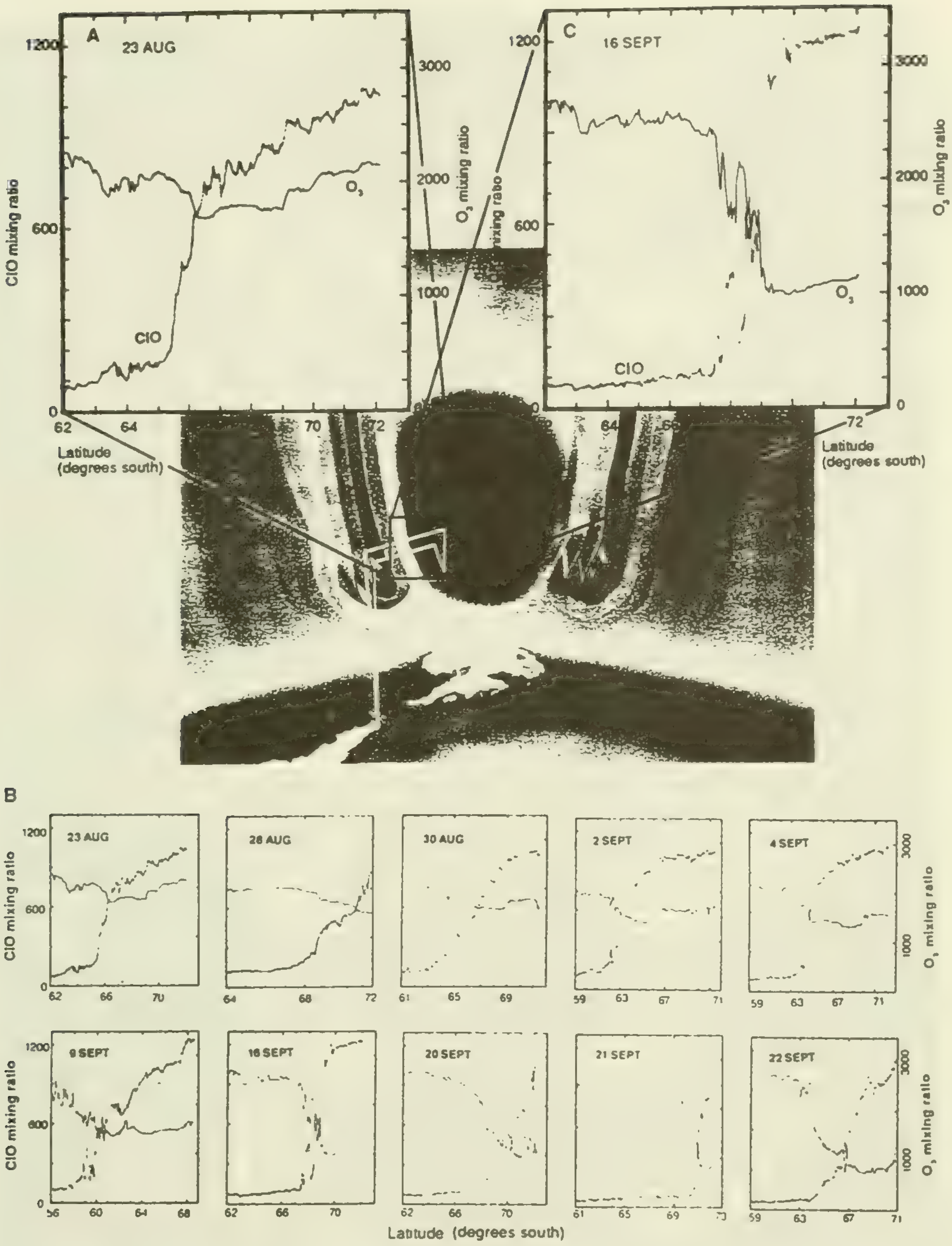

Figure 1. Rendering of the containment provided by the circumpolar jet that isolates the region of highly enhanced ClO (shown in green) over the Antarctic continent. Evolution of the anticorrelation between ClO and O_3 across the vortex transition is traced from (A) the initial condition observed on 23 August 1987 on the southbound leg of the flight. (B) Summary of the sequence over the ten-flight series; (C) imprint on O_3 resulting from three weeks of exposure to elevated levels of ClO. Data panels do not include dive segment of trajectory; ClO mixing ratios are in parts per trillion by volume; O_3 mixing ratios are in parts per billion by volume.

The mission, executed in August and September of 1987 from Punta Arenas, Chile, demonstrated unequivocally that ozone was destroyed by chlorine and bromine radicals. The case linking chlorofluorocarbons, the molecules that transport chlorine to the stratosphere, to the destruction of ozone over the Antarctic, rests on three discoveries from the NASA mission. The first discovery was that the region of severe ozone depletion was isolated from the rest of the stratosphere by the polar night jet that defines the perimeter of the antarctic vortex. This isolation creates a continental-scale "containment vessel" that creates a sharp transition in the concentration of the key chemical species associated with the destruction of ozone. The existence of this barrier preventing exchange is shown clearly by the high-resolution aircraft data in figure 1. The second discovery from that mission linking CFCs to ozone destruction over the Antarctic is the documented evolution of the anticorrelation between O_3 and ClO that occurs within the containment vessel in the stratosphere over the Antarctic. As figure 1 shows, the initial conditions established on 23 August as sunlight returns to the region demonstrates that O_3 had emerged from the polar night largely unaffected. Three weeks later, on 16 September, ozone had eroded sharply in the presence of high ClO concentrations within the containment vessel. The third discovery emerged from laboratory studies that determined the rates of key reactions responsible for destruction of ozone by chlorine and bromine radicals. Those laboratory results allowed the direct, quantitative comparison between (1) the observed concentrations of ClO and BrO obtained by the aircraft within the containment vessel, and (2) the rate of ozone disappearance within the containment vessel observed by the aircraft.

What sets Antarctic ozone depletion apart in the context of global change is both the severity of the phenomenon and the isolation afforded by the containment vessel in the stratosphere over the Antarctic. This testimony has summarized the scientific case linking CFC release to ozone destruction in three parts, all of which have appeared in and been critiqued by the international scientific literature (see Anderson *et al.*, *Science* **251**, 39, 1991). When taken together, the three elements in the case provide irrefutable evidence that the dramatic reduction in stratospheric ozone over the antarctic continent would not have occurred had CFCs not been synthesized and then added to the atmosphere.

NASA satellites have developed maps of the evolution of ozone in the southern hemisphere, as shown in figure 2, that have been critical to our emerging picture of this precipitous phenomenon. The thinning of ozone over the northern hemisphere has been mapped as well by NASA.

Have there been other surprises that have reordered our thinking? In 1989 and again in 1991-92, NASA airborne missions staged from Stavanger, Norway , Fairbanks, Alaska, and Bangor, Maine, revealed that the containment vessel over the Arctic contained highly amplified concentrations of the same ClO radical discovered over the Antarctic. Because ozone destruction requires *high concentrations of chlorine radicals, sunlight and time*, loss over the Arctic is less severe because the slightly higher temperatures over the Arctic allow the system to recover more quickly, reducing the length of time chlorine radicals remain at high concentration within the containment vessel.

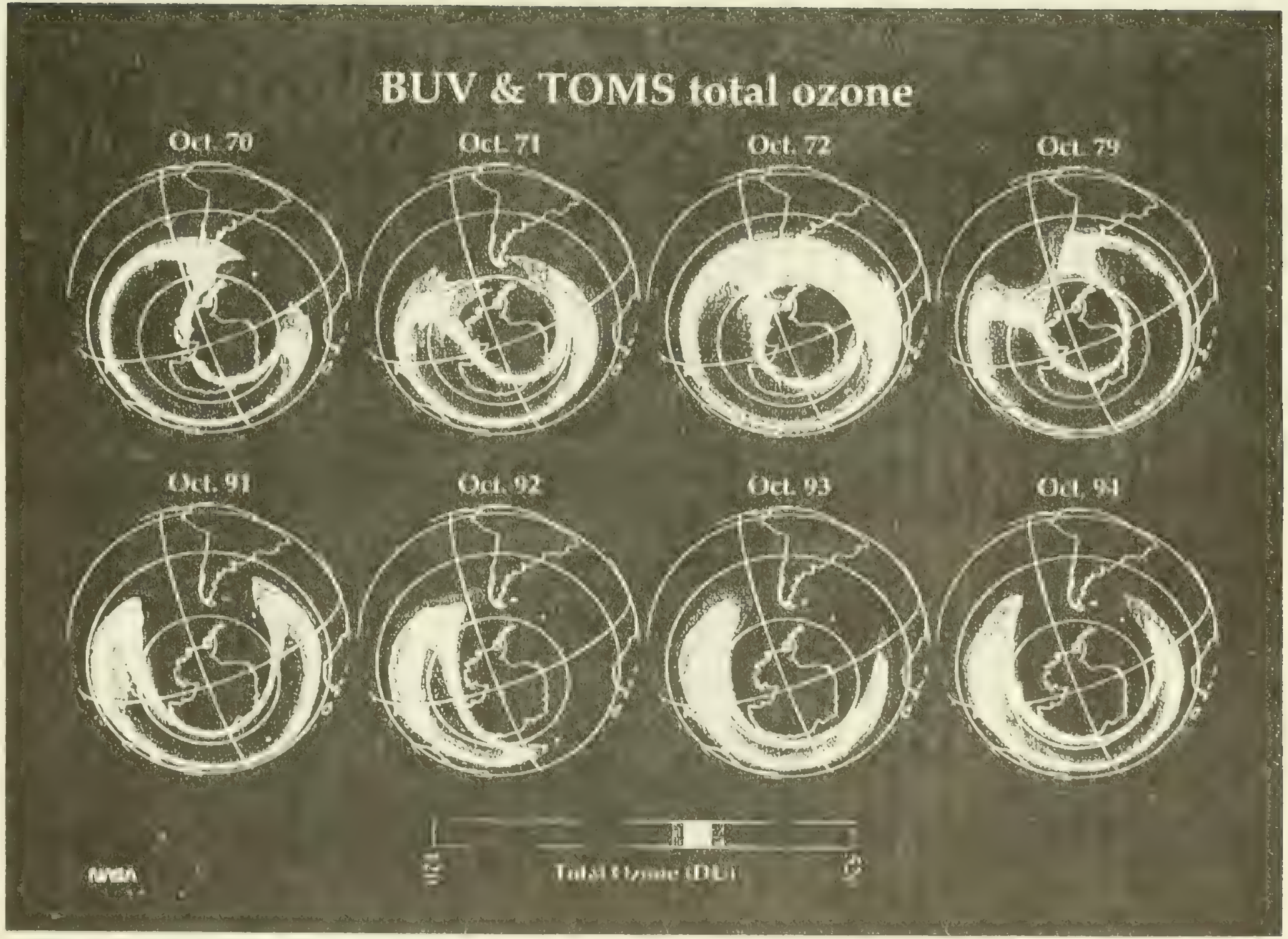

Figure 2. Global maps of ozone in the southern hemisphere, provided by NASA, tracing the emergence of the dramatic ozone loss over the southern hemisphere from the 1970s through to the present.

Are there clear links between discoveries associated with Earth studies and our economic competitiveness? *The United States is the world leader in aircraft design and in the development and sale of civilian commercial aircraft. A research program has been developed at NASA to establish the response of ozone to injections of combustion products (NO_y, H_2O, Particulates) from the proposed High Speed Civil Transport (HSCT). The first direct experiments on the ER-2 recast our understanding of ozone loss in the lower stratosphere.*

Commercial aircraft sales is an international market measured in the $10s of billions per year category. The development of the HSCT is a key component in the international battle for leadership in this field. A key issue associated with this development is that the nitrogen oxide/particulate/water vapor effluent from the proposed aircraft could trigger both enhanced ozone loss in the in the stratosphere and radiative changes linked through water vapor changes and cloud formation to climate changes. Senate hearings in the early 1970s hinged in a significant way on the prospect of damage to the ozone layer by large fleets of Super Sonic Transports (SSTs). Equally important, however, is the recognition that if an aircraft is detrimental to global ozone and/or to climate, business decisions to build such an aircraft are compromised.

NASA has put in place a research effort with airborne missions to execute experiments to test the fundamental tenets of our understanding of the processes that control ozone in the stratosphere and how the proposed HSCT will alter those processes. The past three years have witnessed two key developments in our understanding of the processes that control the catalytic destruction of ozone in the lower stratosphere.

The first development emerged out of simultaneous NO_x/NO_y observations by Fahey *et al.* (*Nature* 363, 509, 1993) of the NOAA Aeronomy Laboratory during the NASA airborne mission to the Arctic: that aerosols (minute liquid droplets) have a dramatic impact on the fraction of reactive nitrogen tied up in free radical form, (NO and NO_2). These ER-2 based, *in situ* observations demonstrated unequivocally that NO_x was converted to NO_y, thereby providing a natural "sink" for any reactive nitrogen compound added to the lower stratosphere, in particular the combustion effluent from the proposed Mach 2.4 High Speed Civil Transport (HSCT). This result constitutes the first serious fissure in the two-decade-old premise that the catalytic destruction of ozone in the lower stratosphere is dominated by nitrogen radicals (NO_x). It was this fundamental tenet that ozone removal rates in the lower stratosphere are rate limited by NO_2, combined with the realization that a significant fleet of supersonic transports would add appreciably to the nitrogen oxide budget of the lower stratosphere, that impugned SSTs in the early seventies.

The second key development emerged from the NASA Stratospheric Photochemistry, Aerosol and Dynamics Expedition (SPADE) mission in May of 1993. That ER-2 mission was the first to include a new generation of solid state laser experiments capable of detecting *OH* and *HO_2*, thereby completing an ensemble of instruments capable of both the simultaneous, *in situ* detection of each of the rate limiting radicals in the dominant catalytic cycles (NO_2, ClO, BrO and HO_2), as well as the detection of the key coupling radicals NO and OH. These ER-2 observations, presented in Wennberg *et al.* 1994 (*Science* **266**, 398, 1994) demonstrated the predominance of odd-hydrogen (HO_x) and halogen free radical (ClO_x and BrO_x) catalysis in determining the rate of removal of ozone in the lower stratosphere. A single catalytic cycle, rate limited by $HO_2 + O_3 \rightarrow HO + O_2 + O_2$, was found to account for nearly half the total O_3 removal in the mid-latitude, northern hemisphere, lower stratosphere. Halogen radical chemistry was found to be responsible for thirty percent of the catalyzed loss of O_3, with reactions involving bromine sustaining half of the halogen catalytic cycles.

Of critical importance to the HSCT was that this NASA mission demonstrated that, in the region sampled by the ER-2, the rate of catalytic ozone destruction is *inversely* correlated with total NO_x loading. The relationship between ozone loss rates and added NO_x is most clearly captured in a figure from Wennberg *et al.* (1994), displayed below in figure 3.

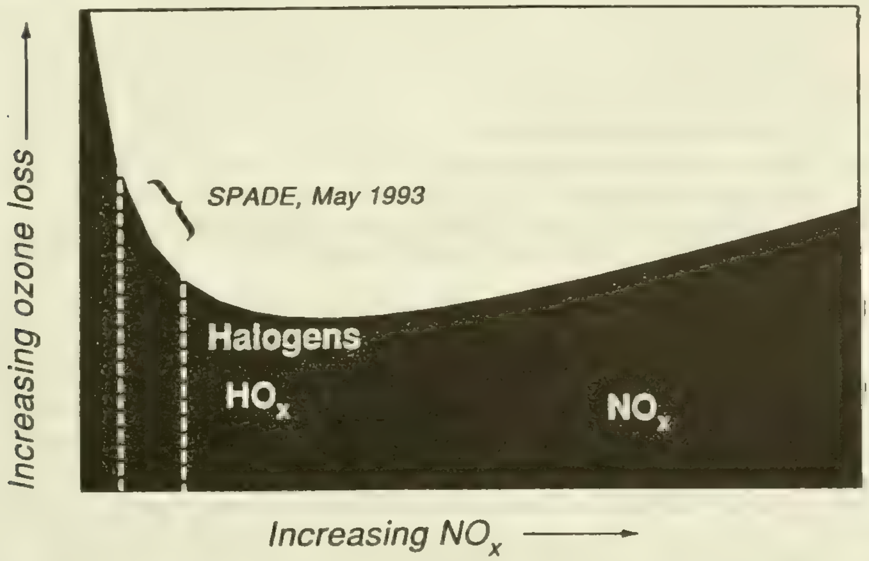

Figure 3. The O_3 removal rate is shown versus $[NO_x]$. Because of the coupling that exists between the radical families, the response of the total O_3 removal rate to changes in $[NO_x]$ is highly nonlinear. At sufficiently low $[NO_x]$, such as observed during the NASA mission, the removal rates are inversely correlated with $[NO_x]$.

These two developments changed decidedly the scientific community's judgment with respect to the expected impact of the NO_x component of the HSCT effluent. Specifically, if there was a region of the stratosphere where the addition of NO_x would actually *decrease* the rate of ozone catalytic destruction, then it becomes plausible, contingent upon the design of the aircraft and the dynamical and chemical characteristics of the stratosphere at higher altitudes, that the addition of NO_x to the lower stratosphere could leave the ozone column virtually unaffected. These ER-2 results decidedly rearranged our thinking on lower stratospheric ozone photochemistry.

What is the relationship between the technology required to investigate the dynamics, radiation and chemistry of the Earth's atmosphere and oceans and the vitality of the technical infrastructure of the United States? *The concept of wishing to lead in the international sale of aircraft, while lagging in the knowledge of the impact of those aircraft, is not a well reasoned policy.*

A new generation of civilian commercial aircraft is a technologically innovative endeavor. It is also a 100 billion dollar market. The analysis of the impact of the nitrogen oxide, particulate and water vapor effluent from those aircraft on ozone and climate is also a technologically innovative endeavor. These studies will, to select some examples, require developments in:

- Optical imaging with electronic pattern recognition
- Microelectronics
- Fault-tolerant guidance systems
- Miniaturized solid state lasers
- Computer controlled laser systems
- High efficiency airfoil technology
- Materials development
- High altitude, long duration autonomous aircraft with robotic-level intelligence
- Rapid response, low cost, small satellite systems

These developments strike to the heart of technological leadership. Their cost must and will be shared by many other technical advances in this country. The scientific questions posed in the pursuit of economic competitiveness eradicate traditional barriers between chemistry, physics, materials sciences, biology, computer sciences, electrical engineering and earth sciences in this nation's universities. Vitality in the U.S. research and development programs hinges on the testing of new ideas with low cost, rapid turn-around approaches and hands-on development placed in the hands of young, emerging leaders of science and technology. It also demands that we return to the ethic of rigorously testing our technological developments as an integral part of any technical innovation.

I have been called as a non-agency witness at a hearing to question national objectives in Earth studies. So I return to the questions posed at the outset. Have we been shocked by discovery? We most decidedly have. In the case of CFCs, the verdict is guilty. In the case of HSCTs, the first round of evidence reversed tenets held prior to direct experimental evidence, opening the possibility that these aircraft can be designed to minimize impact on ozone and climate. Are there clear links to technical and economic vitality? There is indeed a direct link between core technical innovation in this field and United States leadership on world markets.

Mr. SENSENBRENNER. Thank you, Dr. Anderson. Next is Dr. Eric Barron, Director of the Earth Systems Science Center at Pennsylvania State University.

Dr. Barron.

STATEMENT OF ERIC J. BARRON, DIRECTOR, EARTH SYSTEMS SCIENCE CENTER, PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PENNSYLVANIA.

Mr. BARRON. Thank you. I truly believe that the familiar global and regional environments that we have come to depend on are in danger of being altered largely because of human activities and most notably because of the increases in greenhouse gases.

Now, saying that, nobody really argues that those changes are going to impact climate, impact the energy balance of the earth's system. All of the scientific argument resides in how fast those changes will occur, what their magnitude will be, how will it affect ecosystems, how will it affect water and water resources, how will it affect agriculture.

And, my personal belief is that the uncertainties and those scientific issues are large enough and the cost is great enough that we can't justify a mitigation strategy where we sit and attempt to try to maintain a certain level of, say, carbon dioxide emissions. Instead, what it suggests to us is a particular scientific strategy.

The first part of that strategy has to be to monitor. We need to know what is going on.

And, the second part of that strategy has to be we have to do a better job of predicting. Mission to Planet Earth and the Earth Observing System (EOS) are absolutely essential in order to accomplish that monitoring and in order to improve our predictability.

We want to do that so that we can have advanced warning and so that we can limit the costs of adaptation to our national vitality and to our economic security. This means that we end up focusing on specific scientific questions.

Can we do a good job of predicting climate a season in advance, a decade in advance? Can we separate out what humans are doing from other influences?

Can we determine what is going on in regions as opposed to the globe? Can we determine what the impact is to ecosystems, water resources and agriculture?

Earth Observing System plays a critical role. Part of my handout describes a number of those roles.

And, I couldn't possibly go into all of them. But, you can hit a couple of highlights.

Just take the hot scientific debates that are going on right now. How much of the warming over the last century is due to solar influences versus human influences? Without an EOS, we are not going to be able to measure the sun consistently enough to answer that important scientific question.

Another major issue, how much are the aerosols, the particles we are putting into the atmosphere, how much of that is actually negating some of the warming from greenhouse gases? Unfortunately, we can't characterize all the aerosols, their distribution or what they are like in order to answer that question without something like an Earth Observing System.

Another major issue, clouds. Clouds are complicated. Making a prediction of those clouds in models is a number one limitation. EOS will let us characterize the clouds, understand their influence on the energy budget of the earth and also give us the other simultaneous measurements that allow us to do a better job of putting the clouds into those models.

There are all sorts of issues that are at risk, because EOS has already gone through a tremendous number of budget cuts. It's embarrassing to say that we don't know whether ice caps are growing or declining. And, yet this is extremely important in terms of sea level variations and coastal communities.

We don't know where all the CO_2 we put into the atmosphere goes. And, if we don't have some measure of productivity in the oceans with EOS observations, that is going to be in jeopardy as well.

I would like to add just one element. You can go on and on with describing EOS contributions to important issues.

One other element—and that is that I think this mission is really special in a lot of ways. It's special, because there is a large number of excellent scientists that are working on it.

It's special, because we have a data and information system that is going to allow those observations to be useful to a community far larger than the group of scientists that are involved. It's also special, because a huge amount of scientific effort is already going on.

There's a tremendous set of accomplishments that we've already had. Now, I'm just going to take one example, again, here in my last minute to describe this.

What you are looking at there is a single season, spring, of precipitation in 1980. And, in the handout that I have that's in your booklet, these figures are close to the back of it, color figures so that you can look at it.

The key here is that the darker the blue, the more rainfall. And, what I would like to do is see if these models we used to predict the future, can we do a good job of predicting the past, right?

So, if we flipped the page over and you just sort of look at that color scheme and you flip the page over, that's what a climate model used to predict the future comes up with as sort of a past prediction. It's terrible, right?

Now, admittedly, I've taken the very worst variable to show you—temperature and things like that these models do much better. But, if you look at the precipitation, for instance, in the growing areas of this country, that's not something you can be proud of.

One of the things that we are doing is to take that model and—just 30 second left. Take that model and embed it, a high resolution model, better physics, into this model used to produce the future, and this is the type of prediction you get just for the United States.

It may be a little hard to see. But, the improvement is absolutely dramatic.

The Earth Observing System is essential for us to be able to increase our knowledge of the physical processes so we can do an improvement on this still and to validate these predictions. And, I think that's the key—monitoring, giving you an advance warning and enhancing our ability to predict.

Thank you very much.

[The prepared statement of Eric Barron follows.]

Earth Observing System:
Science Contributions to National Goals and Interests

Prepared for Subcommittee on Space and Aeronautics
Hearing on NASA
March 16, 1995

March 15, 1995

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Goddard Space Flight Center

INTRODUCTION

Much of the research underway and planned as part of NASA's Earth Observing System (EOS) is directed toward the highest priority elements of the US Global Change Research Program (USGCRP). In order to elucidate the importance of EOS contributions for national interests and needs, the Science Executive Committee of the Investigator Working Group (IWG) instituted a survey based on the preliminary set of questions and products developed by the USGCRP office and other agencies. The survey was divided into the five major themes, the national needs for each theme, and the products required to answer the most pressing scientific questions directed toward these national needs. These themes are:

(1) Atmospheric Ozone and UV-B Radiation

(2) Natural Variability and Enhanced Climate Prediction

(3) Long-Term Climate Change including Global Warming

(4) Ecosystem Change and Biodiversity

(5) Human Dimensions and Economics.

The discussion which follows is a synthesis of the responses of EOS investigators and an overview by the authors. These responses indicate the importance of EOS. EOS directly addresses national requirements for scientific understanding of atmospheric ozone, natural variability and enhanced climate prediction, and long-term climate change. EOS provides fundamental measures related to ecosystem change and aids in biodiversity research. Much of EOS research is a prerequisite for significant elements of the human dimensions research plan.

A glossary is provided at the end of this document to explain the EOS instrument names used throughout this text.

ATMOSPHERIC OZONE AND UV-B RADIATION

The National Interest

Ozone is a primary shield from harmful ultraviolet radiation (UV-B) and is a significant contributor to the global radiative energy balance through solar absorption and IR radiation.

Scientific Background

The development of the Antarctic ozone hole and the global depletion of stratospheric ozone is well documented from satellite (Nimbus 7 SBUV, TOMS, Meteor TOMS, SAGE II, and NOAA SBUV2), ground based (Dobson network), and in situ (aircraft and balloon) measurements. The depletion of stratospheric ozone has been tied to two major causes. First, ozone depletion is clearly associated with a six-fold increase in stratospheric chlorine above natural levels, in large part due to the human emission of chloroflurocarbons. The increasing levels of stratospheric chlorine have been implicated in the development of late winter and spring polar ozone depletions. Second, significant volcanic injection of sulfur dioxide into the stratosphere can lead to a temporary (several years) ozone depletion apparently associated with the increase of sulfate aerosols in the stratosphere. Although the chemistry of volcanic depletions is not completely understood, the effect can be significant. The eruption of Mt. Pinatubo has been correlated with a 35% reduction in stratospheric ozone at northern hemisphere latitudes. Prior to the eruption of Mt. Pinatubo, the satellite and ground based data showed an additional midlatitude ozone decrease of slightly less than 1%/year. Although some modelers attribute this non-polar trend to industrial chlorine loading of the stratosphere, the exact cause is still under research. Ozone depletion can also be the result of stratospheric emissions for the increasing fleet of sub-sonic aircraft.

Ozone is also a greenhouse gas with strong infrared bands. In the tropics, ozone in the cold lower stratosphere intercepts surface IR radiation, heating the stratosphere. At polar latitudes, ozone cools the stratosphere. Ozone loss will affect the energy balance of the lower stratosphere and upper troposphere.

Heterogeneous chemistry on aerosols plays a significant role in ozone loss. We also know that aerosol formation is temperature dependent. Thus global cooling of the stratosphere due to increasing carbon dioxide may increase ozone loss which in turn would amplify the stratospheric cooling in some regions and increase surface greenhouse warming in others.

Science Requirements to Address National Needs

The detection, causes and impacts of significant changes in stratospheric ozone.

EOS CONTRIBUTIONS

The Earth Observing System addresses critical questions in the national interest including the detection and prediction of ozone depletion, the isolation of human versus natural factors forcing changes in atmospheric ozone, the response of atmospheric ozone to human forcing, and an understanding of the uncertainties associated with ozone depletion. For atmospheric ozone the key questions and EOS contributions are:

(1) What are the long term and short term changes in stratospheric ozone?

Ozone Profiles. HIRDLS, MLS will make daily global ozone profile measurements. SAGE III will make high precision solar occultation ozone profiles as part of the long term trend series begun by the predecessor SAGE I and II instruments. The CHEM international instrument will provide daily column ozone amount. AIRS will measure the vertical distribution of ozone in the troposphere and five layers in the stratosphere using infrared. MODIS will measure total column ozone twice daily with better than 20% accuracy. Both of these measurements can provide a backup for the more accurate HIRDLS, MLS, SAGE III, CHEMI observations.

Calibrated Historical Data Sets. EOS investigators will produce long term calibrated ozone data sets based on earlier Nimbus 7 (SBUV, TOMS), Meteor TOMS, EP TOMS, SAGE I, SAGE II, UARS (MLS, HALOE, ISAMS, CLAES) and NOAA SBUV/2 measurements. The ozone mapping instruments on ERS-2 and ENVISAT will provide additional ozone data sets.

(2) What are the human and natural forcing agents controlling stratospheric ozone? What has been and will be the response of stratospheric ozone and UV-B radiation to human forcing?

* Catalysts. HIRDLS, MLS and SAGE III will measure polar stratospheric clouds and aerosols. These measurements will provide an understanding of the role of heterogeneous and nitrogen radicals which catalyze ozone destructions, the chlorine reservoir species and source gases including industrial chemicals (CFC's), nitrogen compounds and aerosols emitted directly by high-flying aircraft, and volcanoes.

* Stratospheric Clouds and Aerosols. SAGE III and HIRDLS will measure polar stratospheric clouds and aerosols. These measurements

will provide an understanding of the role of heterogeneous chemical changes in producing ozone variability. MLS will contribute measurements which are not degraded by clouds or volcanic aerosols, allowing critical observations in the presence of polar stratospheric clouds and thick aerosol layers which form following volcanic eruptions.

* Stratospheric Temperature Profiles. MLS, HIRDLS and AIRS will provide accurate global daily stratospheric temperate profiles. These measurements, combined with 4D data assimilation, are used to determine the stratospheric circulation and transport. Year to year variation in the stratospheric circulation is a major factor controlling stratospheric ozone.

* Solar UV Radiation. SOLSTICE will make highly accurate solar UV radiation measurements. Solar variation in UV flux throughout the solar cycle are a major factor controlling the global ozone amount.

* UV-B Transmissions. EOS monitoring of clouds and the radiant energy budget will provide a diagnostic measure of the UV-B transmission which is cloud dependent. CERES, AIRS, MODIS and MISR will produce cloud forcing products and cloud radiative properties useful for UV-B analysis.

* Human-Induced vs Natural Depletion. EOS investigators will use the EOS measurements of stratospheric ozone, minor constituents, temperatures, UV flux, and aerosols to separate natural ozone variations from human-induced ozone depletion over the EOS period. These measurements can be linked to previous measurements made by the Nimbus 7 and UARS instrument compliments, the SAGE, TOMS and SBUV/2 satellite instrument series, aircraft and ground based measurement to determine trends in trace gases.

* Chemical Transport Models. EOS investigators will develop 3-dimensional chemical transport models of the stratosphere, in predictive and diagnostic modes, which can be utilized to calculate radical trace gas concentrations, estimate ozone losses, and calculate the UV-B flux. EOS measurements will be used to validate those models.

(3) **What will be the climate impact of changing radiatively active stratospheric trace gases (ozone, water, CFC's, N_2O, etc.)?**

* Detection of Ozone Radiative Forcing Changes. HIRDLS, MLS, and SAGE III make essential contributions to detecting ozone depletion and water vapor trends in the troposphere and lower stratosphere where radiative forcing changes are critical for climate. SAGE III high precision ozone and water measurements are especially important in determining changes since the 1980's since these measurements can be linked to SAGE III predecessor instruments.

* Aerosol Radiative Forcing Changes. SAGE III and HIRDLS measurement of aerosols in the lower troposphere and upper stratosphere are essential in determining the aerosol radiative forcing. Determination of this forcing is especially important in post volcanic eruption periods when formation of thick stratospheric sulfate aerosols layers produce global cooling.

* Water Vapor Radiative Forcing Changes. MLS makes daily, global measurements of upper tropospheric water vapor and temperature through the cloud fields. MLS measurements can be used to assess the radiative forcing of water vapor and can be linked to cloud formation and moisture transport processes when combined with MODIS, CERES and AIRS measurements.

* CFC's and N_2O Radiative Forcing Changes. HIRDLS and MLS make measurements of CFC's and N_2O in the lower stratosphere.

* Assimilated Data Sets. EOS investigators will assimilate the aerosol, temperature, and water vapor measurements of SAGE III, HIRDLS and MLS to produce global meteorological data sets which will be used for climate studies.

(4) **What are the uncertainties and what is the potential for change?**

* Early Detection. SAGE III, MLS and HIRDLS ozone measurements will provide the earliest-possible detection of ozone depletion. Despite the regulation of CFC production, additional ozone decreases will occur in response to the unprecedented high chlorine abundances expected during the next decade.

* Major Uncertainties in Stratospheric Chemistry. EOS chemical measurements (MLS, HIRDLS, SAGE III and SOLSTICE) address major

uncertainties in understanding stratospheric chemistry by measuring the minimum minor constituent set required to understand the processes that control ozone. Those measurements include a radical from each of the major catalytic ozone loss families, the major reservoir gases, the major source gases for those radicals, temperature, aerosols, and UV flux. This set of measurements will be the most complete global measurements since UARS, and is the minimum set required to connect change ozone amounts to chemical processes within the stratosphere.

* Links to Stratospheric Cooling. EOS measurements, including stratospheric temperatures (AIRS, HIRDLS, MLS) will increase our understanding of the potential ozone decrease in response to the stratospheric cooling caused by increasing atmospheric CO_2.

* Aerosols. EOS SAGE III and HIRDLS will monitor the formation of sulfate aerosol layers following volcanic eruptions and the impact of these layers on the natural variability in ozone chemistry and enhancement of the human forcing on ozone depletion. They will provide daily measurements of the location and extent of polar stratospheric clouds which are primary sites for heterogenous chemical reactions which give rise to ozone loss.

NATURAL VARIABILITY AND ENHANCED CLIMATE PREDICTION

The National Interest

The skillful prediction of precipitation and temperature anomalies months to years in the future can yield improved production and distribution of agricultural and forestry products, improved planning for energy generation and utilization, and more effective responses to floods and droughts. The goal is therefore to use short term (seasonal and interannual) climate forecasting for social and economic benefit.

Scientific Background

Predictability on seasonal and interannual time scales has already been demonstrated for some aspects of the climate system, particularly for interannual sea surface temperature changes in the tropical Pacific Ocean and their relation to weather. In addition to its immediate practical benefits, improved short term climate forecasting, because it requires a comprehensive knowledge of the atmospheric circulation and its interaction with the ocean and the land surface, contributes substantially to the predictions of long term greenhouse warming. Verification of short term climate forecasts and resulting improvements in forecasting models contribute directly to the improvement of global greenhouse warming forecasts on decadal and longer time scales, especially the regional variations in climate change. In addition, detection of long term human induced climate change requires an understanding of the natural variability inherent in the climate system which produces most of the variability on seasonal and interannual time scales.

Science Requirements to Address National Needs

(1) Operational predictions of interannual climate fluctuations up to one year in the future. (2) Detection of natural climate variations on decadal time scales and identification of their causes and impacts.

EOS CONTRIBUTIONS

EOS will help define the natural and human factors that influence seasonal to interannual climate. A significant fraction of natural climate variability is governed by interaction of the atmosphere with global sea surface temperature, land moisture, vegetation, snow and sea ice. Additional variability is introduced from solar variability and volcanic eruptions. Human induced modifications of atmospheric chemistry may alter the nature of seasonal to interannual variability. The EOS contributions to understanding climate variability will enhance the ability to predict climatic variations and change from seasons to decades in advance. The key questions and EOS contributions include:

(1) What are the natural and human factors that affect the seasonal to interannual climate and its anomalies?

- Ocean-Atmosphere Interaction. EOS will contribute substantially to the understanding of ocean-atmosphere interactions. Investigators will be able to combine altimetry (TOPEX/Poseiden, ERS-1, ERS-2, TOPEX follow on, and EOS ALT), scatterometry (NSCAT, AMI, Seawinds), ocean color (MODIS, Seawifs, EOS-COLOR), and sea surface temperature measurements (MODIS, AIRS/AMSU/MHS), assimilate these observations into forecasting models and resolve major characteristics of the surface oceans responsible for natural variability. These observations combined with the temperature and humidity measurements of AIRS/AMSU and the cloud-radiation budgets from CERES, will allow investigators to connect sea surface temperature variations with the large-scale and mesoscale circulations and their associated cloud cover, and improve boundary layer models which describe air-sea interaction. Global assimilation of these date will provide operational products necessary for predictions of interannual fluctuations and will also contribute to our understanding of the coupled ocean-atmosphere interactions and the prediction of phenomena such as El Nino. EOS (CERES, MODIS, AIRS and MISR) will provide a strong basis for monitoring variability in cloud properties (amount, type, liquid water content) which may play an important role in natural interannual variability of the climate system. SAGE III, HIRDLS and MLS contribute observations to assess the interannual variability of radiatively active trace gases (ozone, CH_4, F11, F12, nitrous oxides) and water vapor in the upper troposphere and lower stratosphere which may participate in climate variability.

- Land-Atmosphere Interaction. EOS measurements of snow cover, soil moisture, surface temperature, land cover, vegetation characteristics, surface albedo, atmospheric temperature and humidity (ASTER, MODIS, MISR, CERES, AIRS/AMSU/MHS, MIMR) will be essential to initialize, and validate the land component of climate model forecasts and to assess the role of the land surface in governing seasonal to interannual variability at regional to global scales. EOS measurements will provide substantial improvements in comparison with existing capabilities (e.g. AVHRR). The ability of EOS to monitor land-surface energy and moisture fluxes (particularly soil moisture) using a new generation of spatially distributed hydrologic models (based on MODIS, ASTER, AIRS, MIMR and other satellite data) will help to better understand land-atmosphere climate interactions. EOS regional assessments which monitor hydrologic parameters (precipitation, evaporation, water vapor, stream flows, glaciers and snow cover) sensitive to climate change and which incorporate historical observations provide baselines for determining changes in variability.

* Aerosols. EOS will be able to characterize the abundance and properties of natural and human-made tropospheric aerosols which may change the effect of greenhouse gases on climate. MODIS, MISR and EOSP will detect regional and global changes of aerosol distribution and variability of their size. They will be able to track several sources of aerosol (e.g. MODIS observations of fires as a source of biomass burning aerosol). EOSP will also determine the aerosol refractive index, a measure of the aerosol composition. Wind blown dust from arid regions will be monitored for major source regions. SAGE III will increase our understanding of aerosol loading and removal.

EOS will be able to track and characterize volcanic eruptions which produce climatic variability on time scales of seasons to years. MISR and ASTER can track the height of plumes, MODIS and MISR the dispersal of the particulates, TOMS, TES, and MLS the dispersal of SO_2, and MISR, HIRDLS and SAGE III the dispersal of stratospheric sulfate aerosols and the evolution of their vertical profiles. MODIS and MISR can provide a high resolution view of the spatial distribution of stratospheric aerosols and data from SAGE III, MODIS and MISR can be used to monitor the evolution of the size of these aerosols.

* Total Solar Irradiance. ACRIM will provide systematic monitoring of total solar irradiance variations, which are essential to separate anthropogenic forcing from natural variations.

(2) What is the ability to predict climatic anomalies a season in advance and what is the mechanism for verifying, distributing, and using these results? One to two years in advance?

* Seasonal Prediction. Seasonal prediction is based on accurate knowledge of the initial state of the slowly varying components of the climate system, particularly the ocean and characteristics of the land surface such as soil moisture, snow cover and vegetation. The accuracy of these forecasts will likely depend on the accuracy with which we can measure the global state of the earth system. The entire suite of EOS observations which define the characteristics of the upper ocean and land surface will provide important boundary conditions for predictions. EOS scatterometer and altimeter measurements, coupled with in situ measurements, will provide the key data for initializing the state of the upper ocean for seasonal climate forecasts. Global-scale,

near-real-time documentation of anomalies in regional precipitation, evaporation, snow cover, sea ice and cloud cover will allow the state of the land component of seasonal forecasts models to be initialized and verified. MODIS, through its capability to monitor the extent and vigor of vegetation, will provide drought monitoring in semi-arid environments.

In addition, EOS will provide data to test how these boundary conditions interact with the atmosphere and the entire climate system, thus leading to improvements in the prediction model themselves. EOS will provide critical process information on air-sea interaction and cloud-climate interactions which are major limitations in current climate forecasts and coupled atmosphere-ocean-land-ice climate models. EOS observations from the full suite of surface and sounding sensors (particularly for temperature, humidity, clouds and radiation) and 4-D assimilation efforts will contribute to forecast validation.

LONG-TERM CLIMATE CHANGE INCLUDING GLOBAL WARMING

The National Interest

Human activities are leading to changes in the land surface and the composition of the atmosphere with significant potential to cause decadal climate change with potentially significant impacts on energy utilization, agriculture, natural ecosystems, water availability, water quality, and sea level.

Scientific Backgound

The alteration of the land surface modifies the energy-water-vegetation interaction at the land-atmosphere interface. Physically-based models indicate that changes in the surface energy and moisture budgets can have a significant impact on regional climates. Increases in carbon dioxide and other greenhouse gases influence the global energy budget, promoting global warming and related climate changes. The detection of global warming is the subject of considerable debate, as the observing system in place over the last 100 years is inadequate to isolate long-term natural variability from human-induced change, and lacks the capability to determine small changes in global temperature. Consequently, an assessment of global warming is dependent on the predictions of climate models. State-of-the-art general circulation models predict a global warming of between 1.5 and 4.5° C and substantial changes in precipitation and evaporation for a doubling of the atmospheric carbon dioxide concentration. Improved estimates of mean sea level change, on both local and global scales, as a means of detecting the consequences of greenhouse gas induced global warming, is an important adjunct requirement. A climate change of this magnitude will have significant impact on energy utilization, agriculture (drought and floods), natural ecosystems, water resource availability, water quality, and potentially, sea level. However, the potential impact is very different for a 1.5° C warming, as opposed to a 4.5° C warming. The magnitude and rate of global climate change define the potential impact on society.

Science Requirements to Address National Needs.

(1) Plausible scenarios for regional climate and ecosystem change, suitable for impact analysis. (2) Improved estimates of the relative global warming potential for various gases and aerosols, including their interactions and indirect effects of other chemical species. (3) Improved ability to determine the regional sources and sinks for atmospheric carbon dioxide, as part of the monitoring system for greenhouse gas emissions reduction agreement. (4) Reduction in the range of predictions of the rate and magnitude of global warming over the next century (through reductions in the uncertainties of cloud-climate interactions and ocean heat storage). (5) Predictions of anthropogenic interdecadal changes in regional climate, in the context of natural variability. (6) Detection, beyond reasonable doubt, of greenhouse gas induced global warming, and documentation of other climatically significant changes in

the global environment. (7) Improved understanding of the interactions of human societies with the global environment, enabling quantitative analyses of existing and anticipated patterns of change.

EOS CONTRIBUTIONS

The detection of climate change, the reduction in the uncertainty associated with climate change, the improvement of estimates of global warming potential and sources and sinks of greenhouse gases, and improved prediction of regional change, including natural variability, depend on (1) an adequate monitoring capability, (2) improved knowledge of the forcing factors, (3) improved predictive capability to determine the response of the climate system, and (4) an assessment of the uncertainties. The Earth Observing System contributes to each of these fundamental components required to serve national needs. The synergy between many observations and many investigators will allow EOS to contribute understanding of the more complex, yet essential, earth processes, such as the hydrologic cycle. For long term climate change the key questions and EOS contributions are:

(1) What are the human-induced and natural forcing changes in the global system and climate?

Knowledge of the nature of the climate forcing factors is essential to the prediction of future global change. The key forcing factors are modifications to the land surface, changes in radiatively important gases, aerosol loading in the atmosphere and solar variability. With the exception of atmospheric carbon dioxide concentrations we lack sufficient information to characterize or to isolate the important human-induced and natural forcing factors. EOS provides essential information for each major forcing.

* Land Cover Change. MODIS, ASTER and MISR will characterize changes in land surface cover and surface vegetation, with the capability to provide long-term monitoring capability. EOS will provide surface fluxes of energy and carbon with unprecedented accuracy and spatial resolution. In conjunction with historical observations, the human alteration of the landscape can be mapped and utilized to determine the potential impact on climate.

* Radiatively-Important Trace Gases. MOPITT and TES will measure CO and CH_4, and TES will measure H_2O, O_3 and N_2O, all of which are needed to begin to separate human and natural greenhouse forcing. EOS measures of ozone depletion (see section on ozone and UVB) will define the abundances and trends of the radiatively important gas.

MODIS measures of biomass burning will contribute to knowledge of trace gas emissions.

- Aerosols. MODIS, MISR and EOSP will detect regional and global changes in tropospheric aerosols. Sulfate aerosols will be mapped and monitored by SAGE III; total column abundance of aerosols will be measured with MISR; volcanic gases can be measured with TES and MLS. Consequently, EOS will assess the role of volcanism as a natural forcing factor in the global system. The role of volcanism versus human-induced aerosol loading can be deciphered based on the chemical imprint of volcanoes, monitoring volcanic eruptions and examination of trends in aerosol loading.

- Solar Variability. ACRIM will measure solar total irradiance, a fundamental measure of solar variability, which is need to separate human and natural greenhouse forcing. SOLSTICE will measure the total variation of UV, and its contribution to the natural variability of ozone.

(2) What has been and will be the response of the climate system to human forcing?

An assessment of the response of the climate system to human forcing depends on our ability to determine the importance of the major forcing factors and to validate climate model response. The degree to which uncertainties in climate model predictions can be eliminated is also of considerable significance.

- Climate Sensitivity. EOS investigators will complete extensive model experimentation aimed at quantitative comparison of the different human-induced and natural forcing changes. These sensitivity experiments will be completed at both regional and global scales. The response of the climate system will be defined by modeling efforts of the EOS investigators based on a quantitative understanding of the natural and anthropogenic forcing from aerosols (MISR, SAGE III, EOSP, CERES, MODIS, HIRDLS), solar irradiance variations (ACRIM), land surface changes (MISR, MODIS, ASTER), and radiatively important gases measured by EOS (H_2O, CH_4, O_3, CH_4, N_2O, F11, F12) and from other sources (CO_2). EOS provides an unprecedented opportunity to assess the response of the climate system based on the full spectrum of forcing factors.

- Climate Response and Validation of Predictions. The long term measure of water vapor, atmospheric temperature, cloud properties and sea surface temperature (AIRS/AMSU/MHS, MODIS, CERES) are essential to detection of global change. AIRS/AMSU/MHS will determine the three-dimensional structure of moisture in the troposphere and will measure the spectral changes in the longwave radiation going to space which are needed to monitor the effects of climate change, including the role of trace gases in global warming. HIRDLS will measure stratospheric cooling, a major expected signal of greenhouse warming. EOS ALT and other precursor altimeter missions will provide a well-calibrated long-term measurement of absolute sea level. The accurate monitoring and prediction of the mean sea level on a global basis provides a means of detecting the effects of greenhouse gas induced global warming. The identification of sea level rise would have a significant economic and societal impact. The characterization of clouds (CERES, MODIS, ASTER, MISR, AIRS), the radiation balance (CERES), temperature and humidity (MODIS, AIRS/AMSU/MHS), winds (scatterometer, EOS-ALT) and ice and snow cover (MIMR, MISR, MODIS) provide unique capability to validate model predictions.

(3) How do human-induced changes compare to variations and changes in the natural system? Can these changes be detected and modeled?

Measurement of the major climate forcing factors by EOS is a prerequisite for detection of human induced global change beyond reasonable doubt. In addition, EOS observations of the temporal and spatial variability of aerosols, vegetation, temperature, water vapor, ozone and clouds are essential to define natural variability.

* Observations of Climate Variability. EOS will assess variability due to cloud interactions, vegetation changes, carbon/trace gas perturbations, and the major climate forcing factors. EOS 4-D assimilation models will provide a physically-consistent global measure of climate change.

* Separating Natural Variability and Human-Induced Change. EOS investigators will apply these satellite observations to assess the possible cancellation of global warming due to increased greenhouse gas concentrations by aerosol loading of the atmosphere. The monitoring of aerosols, cloud properties, ozone and water vapor will provide a basis for improved estimates of the relative global warming potential of various gases and aerosols, including interactions and indirect effects. The location, duration, and type of activity associated with large volcanic eruptions, which is also a major source of uncertainty, will be

monitored by EOS, allowing an isolation of human-induced and natural aerosol loading in the atmosphere. MISR bi-directional reflectance measurements will distinguish between natural or human-induced land surface cover and surface albedo variations, related to desertification, irrigation, deforestation and urbanization.

* Modeling the Roles of Natural Variability and Human-Induced Change. Characterization of aerosol characteristics (abundance, particle sizes, albedo, optical thickness) with MISR, MODIS and EOSP, in conjunction with cloud measures, can be used to determine the indirect effect of aerosols as cloud condensation nuclei to define the climate impact of aerosols, including their interactions. Measures of CO, and CH_4 assist in the direct measurement of potential global warming. The carbon balance of terrestrial ecosystems from satellites, for different regions and resolutions will yield scenarios for fluxes under different climate conditions or land management conditions. Terrestrial vegetation characteristics and ocean productivity measures will aid in the determination of regional sources and sinks for atmospheric CO_2, N_2O and CH_4.

(4) What are the uncertainties and what is the potential for surprises, including sudden changes and changes in the frequency and intensity of extreme events?

The primary uncertainties in climate model predictions include cloud-climate feedbacks, land-atmosphere and ocean-atmosphere interactions, high latitude ice and snow response and the coarse spatial scale of current climate models. EOS will provide significant opportunities to document surface fluxes of energy and moisture over the land surface and the oceans, to document regional and global radiation budgets required to understand cloud-climate feedbacks, and to determine ocean heat transport. EOS will provide the first opportunity to examine ice sheet mass balance. These elements encompass the major limitation in current climate models, and thus EOS will contribute substantially to the improved prediction of regional and global climate change in the next generation of climate models. These model predictions can be verified by long term observations or can provide estimates of the statistical likelihood of change.

* Cloud-Climate Interactions. Uncertainties in cloud-climate feedbacks are regarded as one of the most important limitations of current models. The unparalleled measurements of clouds, cloud-radiation and water vapor will allow EOS investigators to incorporate much improved parameterizations in climate models.

- Atmosphere-Surface Interactions. EOS observations of surface temperatures, atmospheric temperatures and moisture, surface characteristics and winds will provide major opportunities to address the uncertainties associated with the fluxes of moisture and energy at the land-atmosphere interface and ocean-atmosphere interface and their parameterization in climate models.

- Ocean Heat Transport. Synergistic measurements of temperature and humidity with ocean altimetry and scatterometry will provide a unique opportunity to improve estimates of ocean heat transport, a major uncertainty in our knowledge of the climate system.

- High Latitude Ice and Snow Response. Current observations are inadequate to determine if the major ice sheets are growing or declining. The GLAS instrument will be the first opportunity to address this major uncertainty.

- Sea Level. EOS ALT and other precursor altimeter missions will provide a well-calibrated long-term measurement of sea level.

- Extreme Events. Models developed by EOS investigators provide one of the few opportunities to address the potential of changes in the frequency and magnitude of extreme events, and will also contribute to understanding of the frequency and intensity of other phenomena such as El Nino. Historical and pre-historical examinations of specific regions by EOS investigators will provide information on the frequency of extreme events and potential thresholds.

- Spatial Scales. EOS investigators will utilize improved measurements of surface fluxes and clouds and radiation to develop high resolution model predictions suitable for regional prediction of climate change.

ECOSYSTEM CHANGE AND BIODIVERSITY

The National Interest

Ecosystem function and biodiversity support human society in a myriad of ways and are under multiple stresses.

Scientific Background

Factors affecting the integrity of ecosystems, and their biological complexity and diversity include changing patterns of land use and habitat fragmentation, effects of changing atmospheric composition, including effects of acidic deposition, ozone, and toxics, and possible changes in climate. The prevention of dramatic human-induced loss of species is a major responsibility, both from the view of species as natural resources and from our obligations for global stewardship. Changing patterns of land use directly affect the carbon storage of ecosystems, influencing the global carbon budget, trace gas emissions influencing other trace gases and biodiversity, by altering and fragmenting habitat. Traditional techniques for monitoring and managing ecosystems and biodiversity have been conducted at small scales, reflecting the techniques available and the scientific and management imperatives. As the effects of humanity, including possible effects on the global climate, become pervasive, ecosystem management increasingly requires analysis of large areas, taking into account remote influences via watersheds, mobility of organisms and the atmosphere.

Science Requirements to Address National Needs

The detection of significant changes in ecosystems and biodiversity, determination of the response of ecosystems and biodiversity to the changes in atmospheric composition, UV-B, land use, climate and sea level, and the ability to attribute changes to specific mechanisms so that appropriate management interventions can be made.

EOS CONTRIBUTIONS

The Earth Observing System will map changes in patterns, and attributes of global ecosystems, and monitor rates of change over time. EOS measurements, in combination with models and ground observations will allow global inventories of land cover change, vegetation types, photosynthetic activity, and the extent and patterns of habitat fragmentation. EOS investigators will produce improved models of ecosystem response to anthropogenic and climate effects, extrapolated globally and calibrated with EOS data, for use in forecasting changes. Improved observations of climate, the oceans and volcanic events will provide better understanding of natural disturbances to ecosystems. EOS contributes substantially to several key questions:

(1) How do terrestrial ecosystems respond to changing climate, patterns of land cover change, and other disturbances?

- Simultaneous observations of terrestrial ecosystem, land cover and climate change: LANDSAT and ASTER provide primary observations of land cover, at the spatial scale of natural forest gaps, land clearing and other processes. Global observations using MODIS provide continuous measurements of global vegetation activity as it changes with the seasons, periodic disturbances such as droughts, and long term directional change. MISR provides the information required to correct LANDSAT, ASTER and MODIS for certain effects of the atmosphere, and land surface reflectance critically increasing the reliability of the interpretation of land surface changes.

- Biological productivity and the carbon cycle: Models developed and utilized by EOS investigators will use information from the above sensors as inputs into calculations of the productivity and carbon storage changes of ecosystems, allowing inventoring of changes in biological productivity and the role of terrestrial ecosystems in the global carbon cycle. The same models can be used, once calibrated, to provide forecasts of the effects of climate change, land use change and disturbance scenarios. The results of these models will increase our basic understanding of ecosystems and provide input into decision-making related to forestry, agriculture, livestock production and watershed management.

- Determination of the patterns of terrestrial ecosystems and ecosystem change: Increasingly, biodiversity and ecological complexity are known to depend upon the size and spatial pattern of ecosystems. Many species require minimum area to successfully reproduce and survive; extinction probabilities are known to increase as habitats are reduced in size. In some cases, networks of smaller habitats can be successful if adequately connected by undisturbed corridors such as riparian zones, border vegetation or intentionally managed strips. Other organisms require large areas of habitat, with significant 'interior' areas away from the disturbances at forest, meadow and wetland borders. Remote observations with ASTER and LANDSAT provide direct information on such spatial patterns, and how they change over time.

  EOS investigators will measure changes in land cover patterns in critical areas of the world, and will work with ecologists, systematists and conservation biologists to link space-based information on spatial pattern to ground-based data on diversity. This information will contribute to the large scale understanding of biodiversity and will provide information for use in local, regional and transnational decision-making regarding biodiversity.

(2) **What will be the impacts of global change on marine ecosystems?**

- Ocean biotic responses: Observations of the marine biota, using ocean color from MODIS and SeaWifs, and observations of ocean physical processes (winds and currents) will provide information on the response of the biota to changes in physical factors such as solar radiation, winds and air-sea exchange. Global ocean color observations will provide a global view of marine productivity, and will complement the necessarily sparse network of direct observations. Detailed observations in coastal zones will allow linking of marine biological responses to physical factors, river inputs and pollution. In conjunction with global observations and modeling of ocean circulation, EOS ocean color observations will aid in modeling the role of the oceans in the global carbon cycle.

  Information on marine ecosystems will be useful to decision-makers concerned with the carbon cycle, coastal zones, fisheries, pollution and navigation.

(3) **What are the possibilities for surprises and non-linear thresholds in global ecosystems?**

- Ecosystem models: The direct global observation of ecosystems and the climate and land use change factors which influence them, will provide a larger data base of ecosystem response than has ever before been available. Most ground-based studies do not provide a view of ecosystem changes over time, and at large spatial scales. EOS observations will provide a large data base of examples that may provide scenarios of abrupt changes, which could become widespread if directional climate change occurs. EOS models will likewise explore a wide range of possible global change scenarios. The EOS ecological models include an increasing number of non-linear and threshold responses based on process studies and extrapolation using remote observations and will provide potential scenarios of abrupt change. The synergism of modeling and observation of ecological changes will add credibility to forecasts of potential abrupt changes.

HUMAN DIMENSIONS AND ECONOMICS

The National Interest

The potential magnitude of global change introduces the need to describe scenarios for global change including their limitations in order that national leaders can define strategies for mitigation or adaptation.

Scientific Background

The strategies for mitigation and adaptation may have widely different economic and societal impact, involving health, standard of living and quality of life. Knowledge of the rate and magnitude of global change and its impact at global and regional scales is essential to assess social and economic impact. Even moderate climate change may result in significant changes in the distribution and availability of critical resources such as water. We must be able to understand the nature of the human forcing of global change, particularly land and energy use. Without these scientific foundations, the strategies for mitigation or adaptation may be misguided, resulting in either inadequate or unnecessary policies.

Science Requirements to Address National Needs

Definition of the interactions of global change with the major areas of societal activity, useful for the development of rational adaptation and mitigation strategies.

EOS CONTRIBUTIONS

The Earth Observing System addresses natural hazards, such as volcanism, but most importantly provides a realistic basis for understanding the potential rate and magnitude of global change. Therefore, EOS studies will define the vulnerabilities of water resources, agriculture and ecosystems to climate change. EOS will provide fundamental data sets on land cover change, clearly addressing the need to understand one of the most significant human forcing factors of global change. EOS will also provide fundamental measures of sea level change, a major factor in coastal regions. The key questions and EOS contributions are:

(1) What are the interactions with agriculture?

* Land Cover Changes. MISR, ASTER and MODIS will assess changes in land cover, surface albedo, biomass burning, and productivity as a basis to assess human activity and to define the interactions between climate, land use and agriculture.

- Enhanced Climate Prediction. EOS observations (AIRS/AMSU/MHS) and regional and global climate change predictions from EOS investigators can be the basis for determining potential changes in agricultural yields, agricultural management and implications for land use.

- Radiatively Important Gases. EOS focus on radiatively important gases from agriculture, and ozone plus ozone depletion catalysts may influence management practices.

(2) What are the interactions with freshwater resources?

- Enhanced Climate Prediction. EOS climate predictions at global and regional scales will emphasize the water balance and its sensitivity to global change, providing a major requirement to assess water resource vulnerability to global change.

- Monitoring of Resources. EOS monitors of snowcover and glaciers at a regional and hemispheric level (MODIS, MIMR) provides a basis for short term assessment of a significant water resource component. GLAS and EOS-ALT will measure global ice sheet mass balance.

(3) What are the interactions in the coastal zone and marginal sea ice zone, including fisheries?

- Marine Productivity. High resolution coastal circulation studies, including biology, will provide important data on primary productivity, a key element in fisheries.

(4) What are the interactions with human health, including disease vectors, air quality, and UV-B radiation?

- Ozone Depletion. MLS, HIRDLS and SAGE III provide diagnostic information on ozone depletion by monitoring enhancements in precursor chemical radicals. This gives the capability for providing early warning potentials for increased UV-B.

- Air Quality. TES and MOPITT will provide a large number of measurements (O_3, CO, CH_4, NO, NO_2 and HNO_3) which will greatly aid our understanding of the chemistry of the troposphere.

- Volcanic Hazards. TES, MISR, ASTER and MODIS will monitor volcanic gas hazards in association with major eruptions which have the potential of human impact.

(5) What are the interactions with land use, including soils and erosion?

- Land Cover Change. EOS instruments will provide unprecedented measurement of the scale and magnitude of changes in land cover associated with land use change.

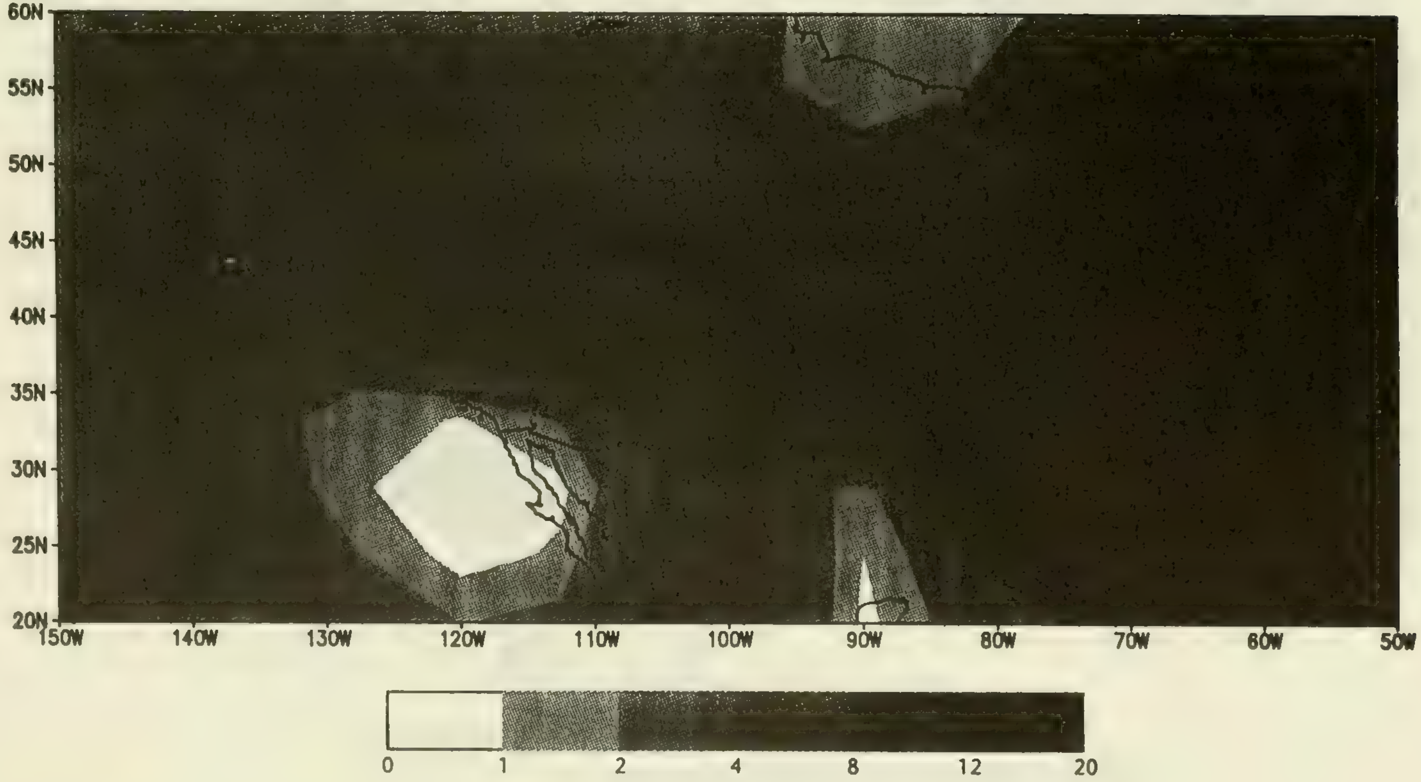
Glossary of Acronyms

ACRIM	Active Cavity Radiometer Irradiance Monitor
AIRS	Atmospheric Infrared Sounder
ALT	Altimeter
AMI	Advanced Microwave Instrument
AMSU	Advanced Microwave Sounding Unit
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High-Resolution Radiometer
CERES	Clouds and Earth's Radiant Energy System
CFC's	Chlorofluorocarbons
CHEM1	Chemnistry Platform Instruments
CLAES	Cryogenic Limb Array Etalon Spectrometer
COLOR	Ocean Productivity
EOSP	Earth Observing Scanning Polarimeter
ERS	European Remote-Sensing Satellite
ENVISAT	Environmental Satellite (European Space Agency)
HALOE	Halogen Experiment
HIRDLS	High-Resolution Dynamics Limb Sounder
IR	Infrared
ISAMS	Improved Stratospheric and Mesospheric Sounder
MHS	Microwave Humidity Sounder
MISR	Multi-Angle Imaging SpectroRadiometer
MLS	Microwave Limb Sounder
MODIS	Moderate-Resolution Imaging Spectroradiometer
MOPITT	Measurements of Pollution in the Troposphere
NSCAT	NASA Scatterometer
SAGE	Stratospheric Aerosol and Gas Experiment
SBUV	Solar Backscatter Ultraviolet
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
TES	Tropospheric Emission Spectrometer
TOMS	Total Ozone Mapping Spectrometer
TOPEX/Poseiden	Ocean Topography Experiment
UARS	Upper Atmosphere Research Satellite
UV-B	Ultraviolet-B

PENNSTATE

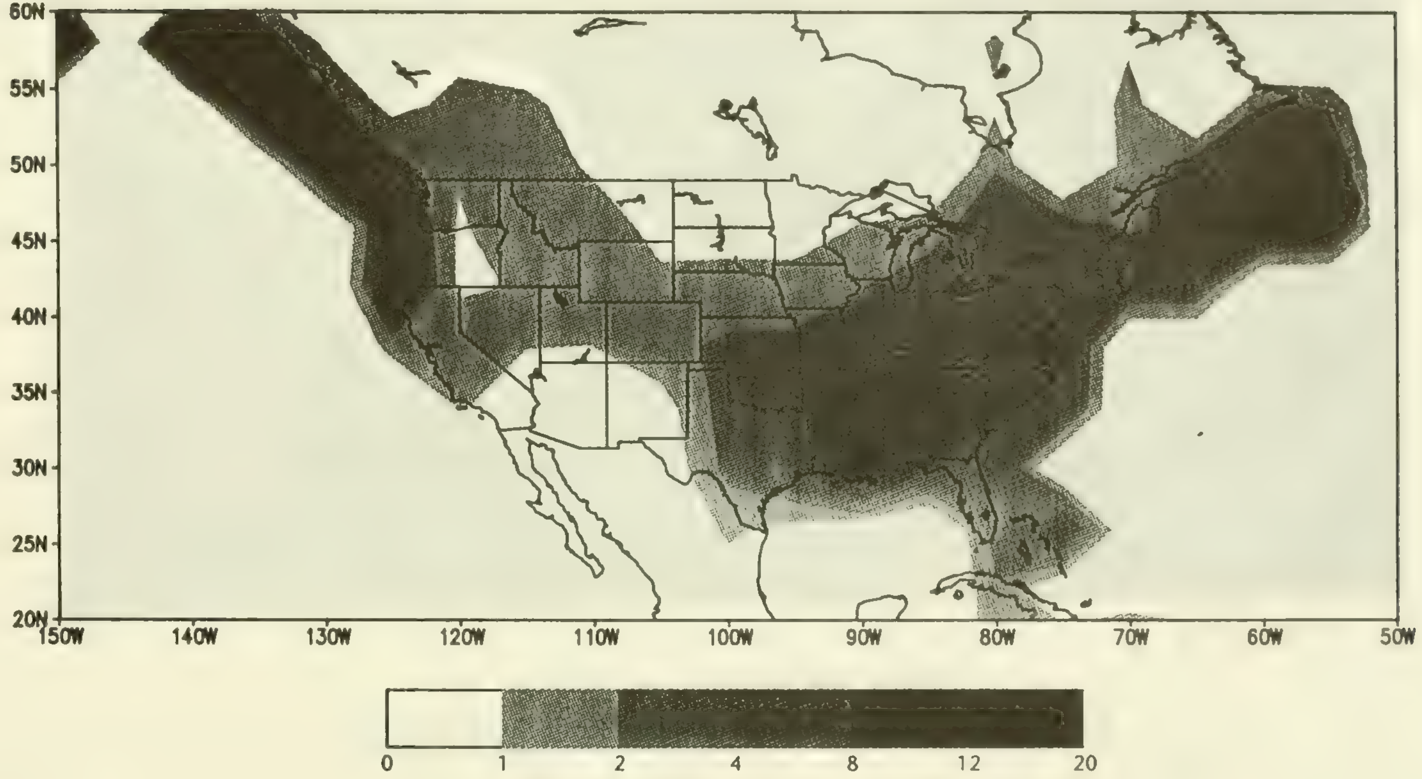
Earth System Science Center

PREDICTED PRECIPITATION (mm/yr)
March-April-May 1980



PENNSTATE
Earth System Science Center

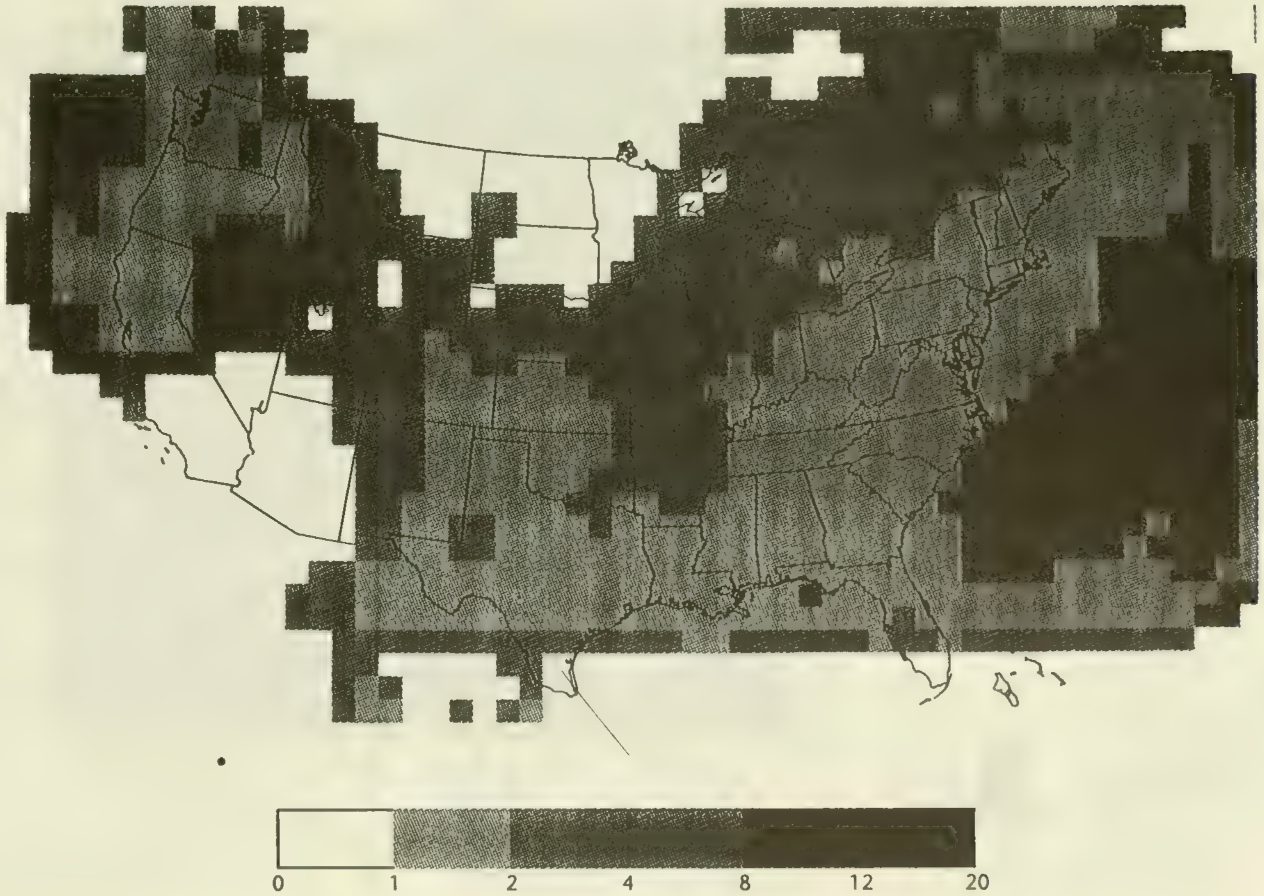
OBSERVED PRECIPITATION (mm/yr)
March-April-May 1980



PENNSTATE

Earth System Science Center

NESTED MODEL PREDICTED PRECIPITATION (mm/yr)
March-April-May 1980



Penn State/NCAR MM Domains

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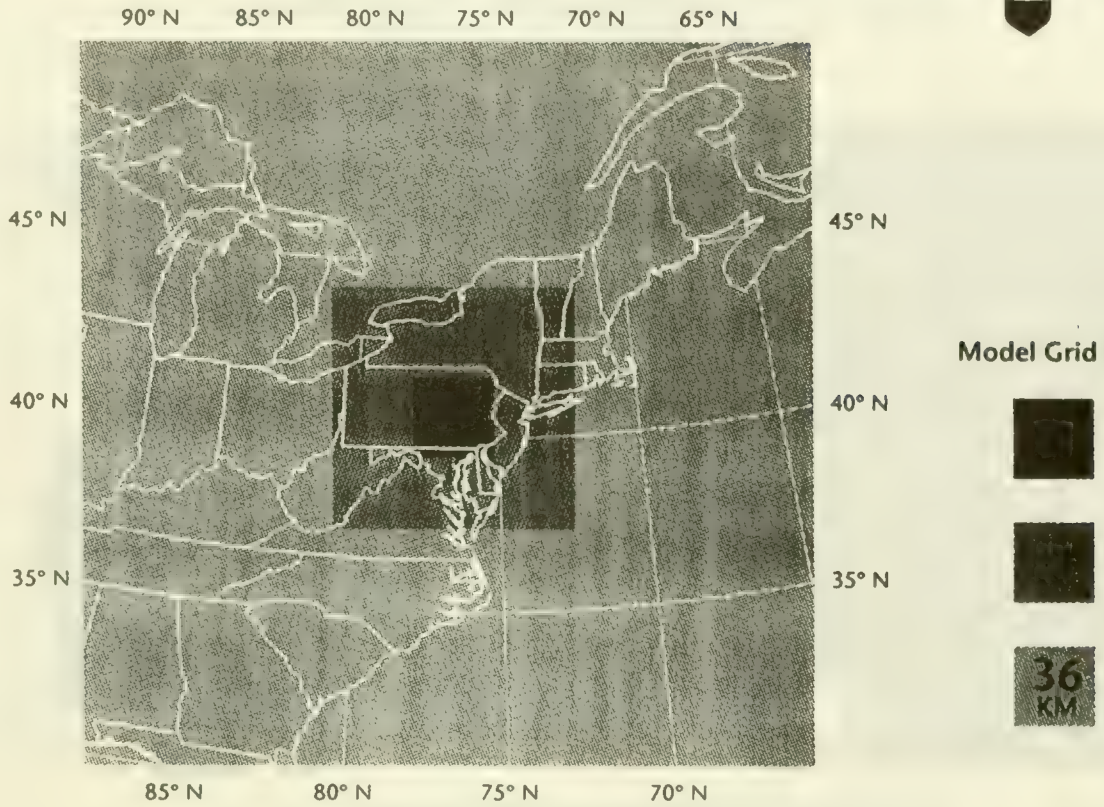

Mr. SENSENBRENNER. Thank you very much. Mr. Brock from GAO.

STATEMENT OF JACK L. BROCK, JR., DIRECTOR, INFORMATION RESOURCE MANAGEMENT/NATIONAL SECURITY AND INTERNATIONAL AFFAIRS, ACCOUNTING AND INFORMATION MANAGEMENT DIVISION, GENERAL ACCOUNTING OFFICE, WASHINGTON, D.C.

Mr. BROCK. Thank you, Mr. Chairman. I would like to just really start building on Dr. Barron's statement.

I think he made a very well articulated assertion that EOS is critical to understanding the earth. He also said that EOSDIS is critical to getting the data out to scientists.

What I would like to focus on today are two risks that we believe that the EOSDIS program is facing that may, in fact, limit its role in the effectiveness of the overall program. I have some material in my statement, which I assume will be included in the full record, which talks about some things that NASA is doing right in responding to the National Research Council (NRC) recommendations. And, I am going to skip that.

But, the two risks that NASA faces are: One, they don't really understand all the users or the user needs. And, they are moving full force in developing a full scale system of EOSDIS in advance of where they should be going right now. I would like to focus, first, on their—I wish I were using that chart.

[Laughter.]

Mr. BROCK. I would like to focus, first, on the user needs. The system right now is intended to serve three classes of users.

The first are principal investigators. And, their needs are fairly well defined.

NASA essentially intends on meeting those needs through a number of standard data sets or data products which really pre-define data, pre-format it. It's easier for NASA to provide that data.

The scientists that are going to be using it have already said, "This is what we need." So, it's relatively easy (for them) to use.

The largest class of users, though, that will be making heavy use of it, the non-affiliated earth scientists, have not really been involved with NASA in saying what their needs are. These needs aren't largely understood and they are not being accounted for in determining the standard data products that NASA is developing.

The third class of users is the non-earth scientists. These are the 200 thousand or so people that NASA classifies as farmers, businessmen, interested parties, school children, whatever, that have an interest in the data who have very little ability or knowledge to get into the data base.

NASA has very little idea, if any idea, of what these needs are and how to address them. The risk of all this is that NASA is developing an information system that is based on a small set of users and with a large set of users unknown and their needs an unknown. We think this is risky.

The second element of risk is that they are focusing very, very heavily on near-term development. NASA wants pretty much a full-scale information system ready for the first launch so that it can fully process the data.

Two problems with this. First of all, as I just mentioned, they don't know the users. If you don't know the users, you are going to have some difficulty in asserting that the system that is available to process and distribute the data will, in fact, meet their needs.

The second issue: This is a massive amount of data that is being accumulated, not just from the satellites but from earth stations, from historical archives, et cetera. The software technology is not yet available to handle this in a facile manner.

There still needs to be a lot of work done on looking at data storage, data communications, data management and data processing. This work has not been done yet.

We believe that NASA should spend more time prototyping, testing, prototyping, and testing to develop these new technologies as they are learning more about what their user requirements are. We feel that if NASA tries to have a full-blown system ready in 1997 and 1998, that it's really precluding itself from having a more facile, more responsive system available for a larger class of users in the future.

This is really the bottom line of my statement, Mr. Chairman. We think that NASA is facing unnecessary risks. This is an important program. It's an expensive program, even though it's being cut back. And, we think it's really unnecessary for the program to accept these levels of risk.

[The prepared statement of Jack L. Brock, Jr. follows.]

United States General Accounting Office

GAO

Testimony

Before the Subcommittee on Space and Aeronautics,
Committee on Science, House of Representatives

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EARTH OBSERVING SYSTEM

Concentration on Near-term EOSDIS Development May Jeopardize Long-term Success

Statement of Jack L. Brock, Jr.
Director, Information Resource Management/
National Security and International Affairs
Accounting and Information Management Division

Mr. Chairman and Members of the Subcommittee:

We are pleased to be here to testify on the National Aeronautics and Space Administration's (NASA) development strategy for the Earth Observing System Data and Information System (EOSDIS). The Earth Observing System (EOS) is a comprehensive program to study global change by gathering and analyzing complete data about how the earth functions as a single, integrated system. Program costs through the year 2000 are estimated to run $7.25 billion. About a third of the cost for EOS will go to EOSDIS, whose success is imperative if the overall program is to succeed. Without the extensive processing, archiving, and distribution functions that EOSDIS will perform, the data collected by EOS' satellite-based instruments will be of little value.

As requested by this Committee, we recently reviewed the EOSDIS program to assess changes NASA has made since the National Research Council (NRC) issued a report on the EOSDIS program in January 1994. Today we would like to address issues and concerns as we see them at this point in our study.

On the basis of our review, we believe that NASA has taken positive steps to address the NRC's concerns. The NRC's primary recommendation was to redesign the system to be more open and distributed, with much more control and responsibility for data processing going to the scientists who will use the system. In response, NASA has revamped the technical architecture of EOSDIS to be more flexible and accommodating to the unique activities and needs of individual data centers and researchers. Key members of the scientific community have endorsed these design changes.

Nevertheless, we have concerns about NASA's development strategy for EOSDIS and its approach to mitigating the significant risks inherent in this large, technically complex project. Today, I would like to discuss our concerns on two subjects related to EOSDIS development: (1) knowing who the expected users of EOSDIS will be and how they will use the system, and (2) finding the appropriate balance between near- and long-term system development needs. I would also like to discuss options that others have identified for improving EOSDIS and saving money. Those options deserve careful attention.

NASA's EOSDIS STRATEGY

Developing EOSDIS is a massive undertaking, both in terms of the system's scope as well as its cost. NASA currently estimates that it will spend over $2 billion to develop EOSDIS through fiscal year 2000. The sheer size of EOSDIS is staggering; its intended scope far exceeds that of any previous civilian data management system. Over its lifetime, the system could accumulate a mass of data equivalent to more than 1,000 times the amount of text stored in the Library of Congress.

NASA intends EOSDIS to be a comprehensive system that will bring together data from many sources to serve the needs of scientists performing integrated, interdisciplinary studies of the earth. In addition to data from the EOS satellites, EOSDIS will include previously archived data; new measurements from other non-EOS spacecraft; various ground-, ocean-, and air-based measurements; and data-processing software developed by the scientific user community. As such, EOSDIS will be the one system responsible for archiving and distributing all NASA earth science data.

The goal of EOSDIS is to make this vast wealth of data easily accessible to as many as 10,000 earth scientists and 200,000 other users from government, academia, and public interest groups. Many of these users will bring little technical background to their interactions with EOSDIS. NASA's intent is to allow scientists and researchers from the many different disciplines to come together and collaborate on global change research in exciting new ways.

The bulk of EOSDIS development will be done under a single, comprehensive contract, known as the EOSDIS Core System contract. The Core System contract was awarded to Hughes Applied Information Systems in early 1993 and will cost NASA an estimated $930 million through 2003. Hughes will be responsible for building and integrating the major elements of EOSDIS, including hardware and software to be installed at eight data centers around the country. The system will be developed through a series of incremental hardware and software releases. A prototype called Version 0, not developed by Hughes, has been running since summer 1994. The Hughes-developed system will first become operational in

1997 to provide data archiving and distribution for the Tropical Rainfall Measurement Mission, and will begin processing and distributing data from the EOS satellites in 1998.

NASA HAS TAKEN POSITIVE STEPS TO ADDRESS SOME OF THE RECOMMENDATIONS OF THE NRC

The January 1994 NRC report on EOSDIS included a fairly broad range of findings and concerns about the planned development of EOSDIS. However, the Council's strongest criticism was leveled at the system's proposed architecture, which it thought was too rigid and centrally controlled. The NRC was concerned that researchers would not be able to go beyond receiving standard, predetermined data products, which would likely be inadequate for research topics that have not yet even been conceived. Furthermore, the Council found that although the system design included eight geographically distributed data centers, control was really centralized at Goddard Space Flight Center. For example, remote users had to go through a centralized office at Goddard in order to log onto the system. Also, only predetermined analyses were to be supported, with no flexibility to accommodate local development of supplemental products. As a result, scientists in the field would be severely constrained in trying to use EOSDIS to manage their own data processing at remote sites.

Fortunately, NASA and Hughes were already making changes to the EOSDIS design by the time NRC issued its report. Since the NRC report was released, NASA has adopted a new, distributed design. Although the heart of the system remains a network of computers at eight data centers that will concentrate on storing data and generating standard products, the new design enables users to share their own research and data products. Users with whom we spoke were generally optimistic that the new EOSDIS design would better enable them to conduct their research.

NASA also deserves credit for strengthening the management of the program and filling vacant positions in the project office with highly qualified people. This is another area that the NRC had asked NASA to address.

Nevertheless, despite the improvements that have been made to the EOSDIS design, we have two major concerns about NASA's approach to developing the system:

- NASA still has not given adequate attention to EOSDIS users, their expectations, or their needs. NASA should take steps to better understand and incorporate user requirements before deciding on critical elements of the system.

- NASA's development strategy may be overly oriented towards large-scale system development work in the near term. Given the uncertainties regarding expected uses of the system and the level of functionality that can be provided, a more modest near-term effort may be warranted.

EXPECTED USERS AND THEIR NEEDS ARE NOT WELL UNDERSTOOD

The system's core users--the community of earth science researchers--are still not effectively involved in the development of EOSDIS. Furthermore, the needs of the large number of non earth science users that NASA expects are unknown. For maximum return on its investment, NASA needs to involve science users more directly in EOSDIS development and better define the broader user community.

For the near term, NASA will need to satisfy the 500 or so principal investigators that it is funding to carry out specific investigations using data from the EOS satellites. NASA's involvement of these investigators to date has been limited to the activities of advisory boards and committees.

The NRC recommended that NASA delegate greater authority, responsibility, and funding to the eight EOSDIS data centers to strengthen their position as representatives of the user community. The eight centers have historically had close relationships with earth science researchers, including the EOS principal investigators, who work in specific disciplines. Because these centers have been responsible for running software written by these researchers and providing analytical results and other automated support, they are closer than NASA project officials to understanding the diverse needs of the core group of researchers who will use EOSDIS in the near term. However, NASA has not yet acted on the NRC recommendation.

Much is still unknown about how earth science researchers will use EOS data. Two hundred and twenty-two standard data products have been designated to be processed and archived in EOSDIS. There has been considerable debate over which of these data products will actually be wanted. Several earth science researchers we contacted said they would prefer access to basic data sets, from which they would derive their own products. Another question is whether researchers will prefer to move EOS data to their own systems for analysis, or whether they will look to NASA to provide them with analytical tools within EOSDIS.

Beyond the near-term needs of the EOS principal investigators and other earth scientists, EOSDIS is intended to also serve a far wider audience. However, very little is known about these other users, which, according to NASA, could span such diverse groups as elementary school students, farmers, librarians, and policy makers. NASA has estimated that EOSDIS will serve as many as 200,000 non earth science users, many of whom will have no special knowledge of remote sensing data or access to sophisticated computers.

Over the years, the NRC has consistently recommended broad user involvement throughout development of earth science data systems to maximize the science return on space missions and improve the quality of data for users. Knowing who will use the systems and how they will use them must determine what systems actually get built. Since NASA does not know the true size of the expected user population of EOSDIS, which data sets will be most needed, or what types of analytical tools users will want, we believe the agency needs to be more cautious about establishing standard data products and other design specifics that could become obsolete or counterproductive by the time the system is in widespread use. At the same time, NASA needs to make a better effort to define the system's expected users and involve them in the planning effort.

CONCENTRATION ON NEAR-TERM DEVELOPMENT MAY JEOPARDIZE LONG-TERM SUCCESS

NASA is currently investing heavily, through the Hughes contract, in near-term, full-scale development of EOSDIS. Hughes has been spending as much as $7.5 million each month on development work aimed at installing all new hardware and software at the eight EOSDIS data centers by 1997, in time to support the first of the EOS-related satellite missions. The existing Version 0 prototype of EOSDIS will temporarily operate in tandem with the new system, but will eventually be phased out.

Such emphasis on large-scale development in the near term may be unwise, for several reasons. As I already discussed, much is still unknown about who will use the system and how. This alone argues for a more conservative, incremental approach to system development. However, NASA faces an additional obstacle as well, namely that critical software technologies needed to ultimately make EOSDIS successful are still beyond the state of the art. Given this condition, greater emphasis on research and prototyping seems in order for the near term, with less emphasis on full-scale development.

The critical software technologies that will be needed are largely associated with handling the vast amounts of science data that EOSDIS is expected to contain. For example, current database search techniques, which were generally designed to meet the needs of transaction-based business applications, are inadequate to support the work of interdisciplinary earth scientists. A new kind of database management system is needed that will handle complex earth science images as nimbly as a business-oriented database system now handles payroll records. Advances are also needed in the way scientific data are organized and characterized within an information system. These technologies do not yet exist in operational form, although some research is underway. Much more work still needs to be done.

Aware of these obstacles, the scientific community advised NASA early in the program to adopt a "build a little, test a little" development strategy for EOSDIS rather than launching headlong into full-scale development. In 1992, we also recommended that NASA develop specific plans and identify resources for prototyping the full range of critical system elements. While NASA has officially subscribed to this "evolutionary" approach, its allocation of development resources nevertheless appears to be overly concentrated on near-term, full-scale development.

NASA is devoting relatively few resources towards research and prototyping activities. NASA-sponsored research projects focused on advanced software technologies for EOSDIS only began last year and are currently funded at a modest $4 million per year. Although more money has gone to prototyping, NASA recently reduced these activities severely when faced with a significant budget cut.

Prototyping is an engineering technique in which partial, experimental versions of computer-based systems are rapidly and inexpensively built to validate requirements and test the feasibility of key functions before production. Taking an evolutionary approach means relying on a substantial ongoing level of prototyping activities to evaluate new concepts and implementations as they are invented.

However, following the rebaselining of the EOSDIS project in July 1994, NASA applied steep cuts to prototyping. Funding at the project level was cut from $69 million to $49.5 million, a 28 percent reduction. Funding for Hughes to conduct future prototyping work was also cut 64 percent, from $72 million to $26 million. In comparison, overall spending for EOSDIS was reduced by only 10 percent. Furthermore, project officials told us that future reductions in the EOSDIS budget would again impact directly on funding for developmental prototyping. This de-emphasis on prototyping clearly jeopardizes the "build a little, test a little" strategy.

By choosing this strategy, NASA has attempted to preserve the substantially larger and more costly effort by Hughes to develop a complete, new data system for the near term. Although Hughes plans to use commercial-off-the shelf hardware and software wherever it can, extensive software development is still needed. Standards for large, distributed database systems are not yet fully developed, and there is no commercially available software to implement many of the required functionalities. As a result, Hughes estimates that over 1 million lines of code will have to be written in-house. Approximately 22 percent of the overall contract costs is allocated to system development. Actual costs may well prove to be substantially higher.

We recognize that NASA needs a system in the near term to provide data handling for the satellites that will be launched beginning in 1997. However, it appears reasonable and prudent to limit this near-term development to a smaller-scale effort. While the existing Version 0 system does not have the capacity to support the upcoming satellite missions, it could be enhanced to provide such support at least on an interim basis. Deferring full-scale development would allow a better, more appropriate system to be designed and built later, when technology and standards have further advanced and user needs are better known.

OPTIONS FOR RESTRUCTURING EOSDIS DEVELOPMENT DESERVE CAREFUL CONSIDERATION

The scientific community has also been concerned about the approach NASA is taking with EOSDIS. In December 1993, NASA's advisory panel of scientific users suggested that NASA commission independent studies of alternative architectures for EOSDIS that could result in a better, cheaper, and more easily evolvable design. NASA responded by commissioning three teams of independent university researchers to examine alternatives to the planned architecture, or overall design, of EOSDIS, at a cost of over $1 million. These teams reported their results to NASA in September 1994.

The teams offered a range of recommendations for improving the effectiveness of EOSDIS and saving money. Some recommendations had to do with specific implementation details while others made significant changes to the system's overall architecture. NASA appears to be making a good effort to address the recommendations having to do with implementation details, but it has not considered making any high-level changes to the system's architecture.

The proposed architectural changes are largely aimed at trying to streamline near-term development and be more responsive to users. For example, one team suggested that greater effectiveness, as well as substantial cost savings, could be gained by reallocating the roles and responsibilities of the data centers. Under this proposal, large-scale data processing and archiving would be confined to two "super" data centers, which presumably could do the job more efficiently and cheaply than eight, as currently planned. The remaining data centers would be freed up to concentrate on their primary role of interacting with scientists and responding to data requests. In fact, since a smaller investment in new hardware, software, and system support would be required at each of these centers, additional centers could even be added without increasing the overall cost.

The two other teams, while not recommending the same approach, also suggested modifications in the number of data centers and their roles and responsibilities in an effort to be more responsive at a lower cost.

We have not had an opportunity to examine in detail the expected costs and benefits of the alternative architectures and thus cannot make a final determination on which, if any, NASA should adopt. However, we believe that NASA needs to look for ways to scale back its near-term systems development effort and take a more cautious approach with greater user involvement. These studies show that alternatives to the current EOSDIS architecture are possible that may help achieve those ends.

In conclusion, Mr. Chairman, I would like to stress that for EOS to succeed, EOSDIS must work well. EOSDIS will be the critical link for turning the data that are gathered by the EOS satellites into useful knowledge about global change. NASA has made good progress in defining a technical architecture for EOSDIS and, in that regard, has responded well to the findings of the NRC.

However, further adjustments could both save money and enhance the system's effectiveness. NASA needs to look at ways to bring users into closer collaboration on system development. The agency also needs to reexamine the pace of system development to see if too much development is being done too early, and too little is being invested in needed research and prototyping. In making that assessment, NASA needs to be realistic about what enhanced functionality can be provided in the near term, given technical as well as resource limitations. The alternative architecture studies that have been completed may offer valuable options for scaling down near-term development and enhancing user involvement.

Mr. Chairman, this concludes our testimony. We will be happy to answer any questions you or other members of the Subcommittee may have at this time.

Mr. SENSENBRENNER. Thank you very much. Dr. Teller, are you ready to testify?

Mr. TELLER. Indeed, I am.

Mr. SENSENBRENNER. Thank you, sir. You are recognized.

STATEMENT OF EDWARD TELLER, LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CALIFORNIA.

Mr. TELLER. Thank you, sir. It's a great privilege. I will try to be brief. I will answer any question. Whether I have an answer or not, I will give it.

[Laughter.]

Mr. TELLER. In my opinion, looking back on the earth is an extremely important enterprise with the recent developments of electronics and with the fortunate changes in the international situation making international cooperation more easy. There are new methods of doing this with relatively small, a couple of hundred pound satellites, great numbers of them, could give very complete data for the order of a billion dollars a year, which could also be very useful.

Since we know what we are looking for, since we can refer questions, have a flexible computer program, we don't need the expensive man on the satellite. Having developed the facilities for man in space will not have been a useless operation.

I brought along a chart here. This is the south pole of the moon.

The south pole is precisely in the middle. You have there a deepening. The moon is only slightly inclined to the ecliptic 60 degrees. The bottom of that deepening has never seen, at least for the last billion years, the sun.

I claim that if we want to go beyond the earth, man in space will be very useful on the moon, much more easily than on Mars, for there we could get a lot of data. And, right there in the middle of the moon—incidentally, this picture was obtained by the relatively light, unexpensive Clementine, altogether costing, this operation, only 80 million dollars. Beautiful pictures where the sun has never shone in a billion years.

You have a steady environment, very adapted to manned occupation and also probably—there are already signs of it although no proof—a deposit of ice as a source of water of extreme importance.

But, let me now return to the main point, looking back on earth. I say a billion dollars approximately. I say hundreds, maybe one thousand small objects.

And, I now will, because I am supposed to be brief, just tell you the purpose of all this. More purposes, more useful things than I can think of.

But, I want to bring to your attention three particular uses. One, intelligence, military. To know where there is population, either for proliferation or for complete aggression, this will not solve the problem of earth peace but without such knowledge and without such knowledge where the raw data are all probably available in the world, the problem will never be solved. If this data is available, aggression will not have become impossible.

But, if there is to be aggression, the world will know about it ahead of time, all the world. And, therefore, measures to combat it will become more possible, because they are more realistic. One purpose.

Second. An incredible improvement on weather data, not only as now in the United States and Europe, to some extent Russia, but all over the world very particularly, including all over the oceans, these satellites being at a distance from each other and from the earth, all approximately 200 miles or a little more. You get the minute-by-minute information of all the meteorological data, including what I consider the most important, wind velocities at all altitudes to be obtained by modern lasers which we are developing in Livermore, for instance.

The result. Not weather prediction without limit. That, on account of Keis' theory, is impossible.

But, today weather predictions are varied for about five days. I claim that with this greatly improved data we can get weather predictions that are reliable for two weeks.

I think, for us all over the world, for farmers, for financial people, for people in charge of transportation in the air or the oceans, the weather predictions are incredibly more valuable than one billion dollars a year. I think it will be a real change that, incidentally, might have the remarkable consequence of transforming meteorology from an art into a science.

Number Three. Today, we are worried about the environment. I believe that in many cases, very many cases, we are overly worried.

It is stated that all restrictions due to worries about environment, we are additionally spending in the U.S. alone more than hundred billion dollars a year. And, who knows how much over the whole world?

With this system of small observing posts close by all the time, we will know all the pollutants. Whatever you want to discuss, the data will be available.

Not only that, the effects of data can be studied. I think it will then turn out that of all the restrictions that we are now putting on on account of environmental protection, a few are necessary but this few will be much less expensive. And, again, the savings will be very great.

So, gentlemen, here you are. On earth, with unmanned systems, and I hope with international cooperation and in a manner where the raw data are open throughout the world, we can serve, foreseeing the days of aggression, understanding weather two weeks ahead of time and understanding the dangers for the environment.

These are relatively unexpensive programs, the total hopefully not exceeding much—perhaps not exceeding at all—a billion dollars a year. And, this is, I think, what should be the number one requirement on NASA.

Thank you very much, Mr. Chairman.

[The corrected oral statement along with the prepared statement of Edward Teller follow:]

ORAL TESTIMONY

Thank you, sir; it is a great pleasure to testify. My written testimony is attached. The following is a version in which brevity is emphasized.

Looking back on Earth is extremely important and can be done in a greatly improved way compared to the situation ten years ago. There are two reasons for this: the first is the remarkably rapid development of electronics and programmed computers. The result is that the weight of observation satellites can be reduced to 200 lbs. with corresponding reductions in expense. The second reason is improved international relations, easing deployment.

The most expensive element in space is man. Since we know what we are looking for and because computers can solve complex problems in a flexible way, the Earth observation phase can be executed in an unmanned fashion. Man in space remains important when it comes to distant travel where we run into the unexpected and therefore complete programming is impractical. This is discussed in the second portion of my written testimony. Here I will take it up first.

At the end of the written testimony you will find a reproduction of a picture of the South Pole of the moon. The South Pole is in the precise middle of the picture which happens to be deep so that the sun has not reached that position for at least a billion years. This is an appropriate place for a permanent lunar colony. While the temperature is very low, it is steady and the absence of variation makes it easier for permanent habitation. There are also signs of a deposit of ice made possible by the absence of solar heating. If confirmed, the availability of water is of great importance. A final advantage is ready access for Earth and easy shielding from Earth at any time.

I now return to the main job: looking back at Earth (MTPE). For not much more than $1 billion per annum, we could keep in orbit at an altitude of 200-300 miles above the Earth' surface possibly as many as a thousand 200 lb. satellites for providing a steady, simultaneous watch over the whole Earth.

Of the many possible observations, I emphasize three. One is military intelligence connected particularly with problems of proliferation of weapons and of aggression. With appropriate prompt publication of the raw observations, secret proliferation and secret preparation for aggression will become impossible. This will not solve all connected problems, but worldwide awareness of upcoming dangers will make a solution much more easy.

The second purpose of the observation system will be great improvements in weather observation, particularly over Third World countries and even more so, over the oceans. The minute by minute information made possible by the use of lasers concerning clouds and winds at all altitudes will result in good weather predictions over the whole Earth two weeks in advance (rather than five days as is at the present time). The benefits to agriculture and to transportation by air and water are obvious.

The third application is to observe the environment. Planned environmental regulations throughout the world involve worldwide expenditures and losses exceeding $100 billion a year. Finding pollutants and the change of concentrations in carbon dioxide and ozone will make it much easier to determine what environmental regulations are clearly needed. It should be noted that not only the presence, but the effects of pollutants and claimed pollutants should be studied.

In summary, for an amount of money, small compared to the budget of NASA, we can obtain great contributions toward preventing aggression, predicting weather and taking rational measures connected with the problems of pollution.

EMBARGOED UNTIL RELEASED BY THE SUBCOMMITTEE

PREPARED INVITED TESTIMONY

ON

THE U.S. SPACE PROGRAM

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE & APPLICATIONS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

BY

DR. EDWARD TELLER

March 16, 1995

INTRODUCTION

The United States Space Program has been most successful in its initial phases. I was in a fortunate position of having advocated a vigorous program on November 25, 1957 to the Committee on Armed Services, right after the launch of the first Soviet Sputnik in 1957. Such success was important in public relations by establishing the basis of a military program as well as the basis for pure research and, last but not least, in stimulating our technological development in a general way.

Most of the military space program is and should be under the jurisdiction of the Department of Defense. I shall, therefore, refer to it only in so far as it is inseparable from the other parts of the program.

Today, after the passage of almost four decades, the broad space program has greater potentialities than ever. The most promising possibilities for progress are not sufficiently being pursued, although the corresponding programs need not be particularly expensive. Today, I want to advocate two such programs which, in my opinion, deserve the greatest possible attention.

One is the deployment and utilization of at least several hundred small satellites in near-Earth space. These should be unmanned, should utilize to the maximum extent modern electronics and related technologies and should be used for the observation of Earth. This system of satellites would have many practical applications, including early warning of military dangers, weather observation and weather prediction and finally recording of actual and possible pollution of the atmosphere.

A second and basically different development which I recommend would be a permanent colony on the Moon for the multiple purposes of finding out all data about the Moon, using the Moon as a base for astronomical observations and finally developing on and near the Moon a refueling station that would enable us to more inexpensively and expeditiously to explore the whole solar system.

In my present proposal, three programs are deliberately omitted.

One is that part of the work in near-Earth space which can be carried out by private industry. This specifically includes the important fields of communications, including a worldwide telephonic system in space, and the exploration of terrestrial resources by observation from space. I believe that these fields have reached levels of maturity where free enterprise can take over and the government need not and should not compete.

The second area consists in the most important space applications for national defense, in particular, defense against missile attack. Work in this field is best carried out by the military, both by the forces of the United States and by appropriate international organizations.

The third field that I am omitting is the exploration of the solar system, including a manned mission to Mars. Actually, small unmanned spacecraft such as *Clementine* have already done valuable work in this field and similar efforts should be continued on an expanding scale, but a concentrated effort on the exploration of the solar system will benefit from soon-to-be-available technology and thus can be carried out in a much more effective manner in the not-too-distant future.

There is one opportunity for immediate action that should be considered. The Soviet SS-18 ICBMs could be used to support many important types of space missions since these could be launched carrying nuclear-based power generators. They would be crucial on missions (e.g., at great distances from the Sun) where a lot of energy is needed and solar cells won't suffice. Since the Russians are prepared to launch nuclear materials while we are not, this prospect should be given serious consideration.

NEAR-EARTH OBSERVATIONS

Gathering information about the Earth from near-Earth space is potentially of immense value. I propose that such observation be carried out by advanced electronics, governed by modern computers, and, at the highest level, by human decisions on the Earth's surface. We actually know what the questions are that we want to have answered and what the apparatus needs be in order to obtain the answers. Human presence in space makes the enterprise very much more expensive and hardly more effective. Consideration of the detailed examples to be given below will, in my opinion, bear out this point.

In this entire development, use of small satellites is advocated because all truly necessary equipment can be carried in packages of a couple of hundred pounds.

Emphasis is to be placed on low-Earth orbits in the neighborhood of 200 to 300 miles above the Earth's surface. For passive data-gathering where the signals decrease as $\frac{1}{r^2}$ and the mass of the detector is increasing as r^2 (r is the distance from the Earth's surface), low or high altitudes are comparable in effectiveness since at high altitudes, the numbers of satellites needed for complete coverage decreases as $\frac{1}{r^2}$. There is, however, a radical change if one considers observation by active means such as RADAR or LIDAR (employing microwaves or lasers). In this case, the signal decreases as $\frac{1}{r^4}$, and observations from great distances such as geosynchronous orbits become impractical.

The low-flying satellites proposed here may stay in orbit for only five years. However, contemporary development of electronics and computers is so fast that in such intervals the equipment on the satellite is apt to become obsolescent. Thus, use of low altitude orbits is not a disadvantage.

Finally, the employment of inexpensive low-flying satellites would permit us to make some mistakes. The resulting flexibility would permit faster learning and overall development.

An important application of numerous low-flying satellites (at least a few hundred of them) would make it possible to observe large-scale developments of means of international aggression or deployments in preparation for aggression. This in itself is not sufficient to stop proliferation or prevent aggression. Such observations, however, would be most helpful in preventing proliferation or deterring aggression. Together with a great reduction in secrecy and the swift international availability of the relevant raw data, these observations would constitute a necessary though not a sufficient measure to stabilize international relations.

A second application of these small satellites would be worldwide observation of weather conditions giving an instantaneous picture of all relevant data, particularly of clouds and wind velocities at all altitudes. At the present stage, our ability to predict weather is not limited by our ability to compute but by the scarcity of pertinent meteorological data. Today, weather predictions have validity for a period of five days. I estimate that, with data continuously supplied by a thousand satellites, weather predictions for two weeks would become feasible. This would hold for every part of the globe. The cost to install and maintain a thousand small satellites in orbit may be of the order of $1 billion per annum. The value of the information received would be obviously much greater.

Regulations for the purpose of limiting environmental pollution have postulated pollutants such as carbon dioxide, freon and other substances and impose a present burden on the world economy which probably exceeds a hundred billion dollars per annum by a considerable margin. The observations obtained from the proposed satellites would be useful in keeping track of these pollutants, finding their human or natural origins and also observing and interpreting their effects.

All three applications enumerated above would be helpful to every country in the world. Deploying and maintaining the system should be an international responsibility. It is excellent news that NASA has already moved to collaborate with the Russians whose highly cost-efficient technology in the launching of satellites is certainly of interest. At the same time, practically every nation could cooperate at least by making available facilities on the ground for sending or receiving signals. In this connection, it is of great interest to discuss the alternative of locating the atmosphere-probing lasers on the ground, or on drifting barges on the ocean, and using the satellites mainly to receive and evaluate the signals and also to steer the laser emissions (including variable wavelength and direction) according to the needs of an appropriately flexible program.

In conclusion, it should be stated that the program outlined in this section would not have been feasible ten years ago. Today, it has become feasible due to the development of modern electronics, computers and spacecraft component technologies, as well as to the lessening of international tensions which makes worldwide cooperation a practical possibility.

A PERMANENT LUNAR COLONY

In the previous section, I advocated intensive use of unmanned space instruments. In contrast, real progress in the utilization of the Moon requires human presence. In the case of the near-Earth satellites, we know what we are looking for. If we land on the Moon or on another planet, we are faced with a situation full of surprises. Fortunately, we have developed the technical means to put man into space and make him useful there. That ability will pay off when we explore the Moon and later when we land on more distant objects.

Our failure so far to establish a lunar colony deprives us of all but the most superficial knowledge concerning the Moon. I am deeply impressed by the range of information that we could gather about the Moon. Since Mars is, under favorable conditions, a few hundred times farther than the Moon, information from that planet will be more expensive and therefore will take much more time to obtain. For this reason, I urge that we concentrate in the near-term on a lunar colony.

In this connection, I want to draw attention to a remarkably successful exploratory action: observations obtained from *Clementine*. *Clementine* is a small spacecraft whose construction and operation by the Naval Research Laboratory, the Air Force (and SDIO, NASA) and the Livermore National Laboratory has cost only $80 million. It has obtained the best and most complete images of the Moon. I am attaching with this document a composite picture created from the *Clementine* data of the region near the southern polar region of the Moon.

In discussing a lunar colony, it is useful to consider some concrete details even if recommendations can hardly be final at this stage. I would like to suggest a manned station of half a dozen people with the occupants being rotated every several months or perhaps longer. For the location of this station, I recommend the bottom of the deep basin near the South Pole of the Moon, which occupies the very center of the attached picture. The rays of the Sun never reach the bottom of this basin.

The reasons for such a recommendation are in my mind not conclusive but still worthy of consideration. The presence and absence of solar irradiation give rise to extreme temperature differences. For the day-to-day operation of a base, it will be simpler to handle constant temperature conditions rather than widely varying ones.

The second reason is that in the absence of solar radiation, small craters made by meteorites colliding with the Moon remain relatively undisturbed. These small craters can be used to study the past of the Moon. The deep and wide basin near the Moon's South Pole is an ideal location for such a study.

At the same time, near the South Pole, water or rather ice could be preserved. Observations from *Clementine* are consistent with ice deposits in this basin.

Proceeding from observations of the Moon to astronomical observations, a location in the southern basin has a twofold advantage. At any time, members of the colony may move relatively short distances and be either in or out of touch with the Earth. On the one hand, they can move to locations where they can communicate with the Earth; on the other hand, they can observe cosmic radio waves without being disturbed by emissions from the Earth. It also may be a significant advantage to have telescopes permanently shielded from solar rays.

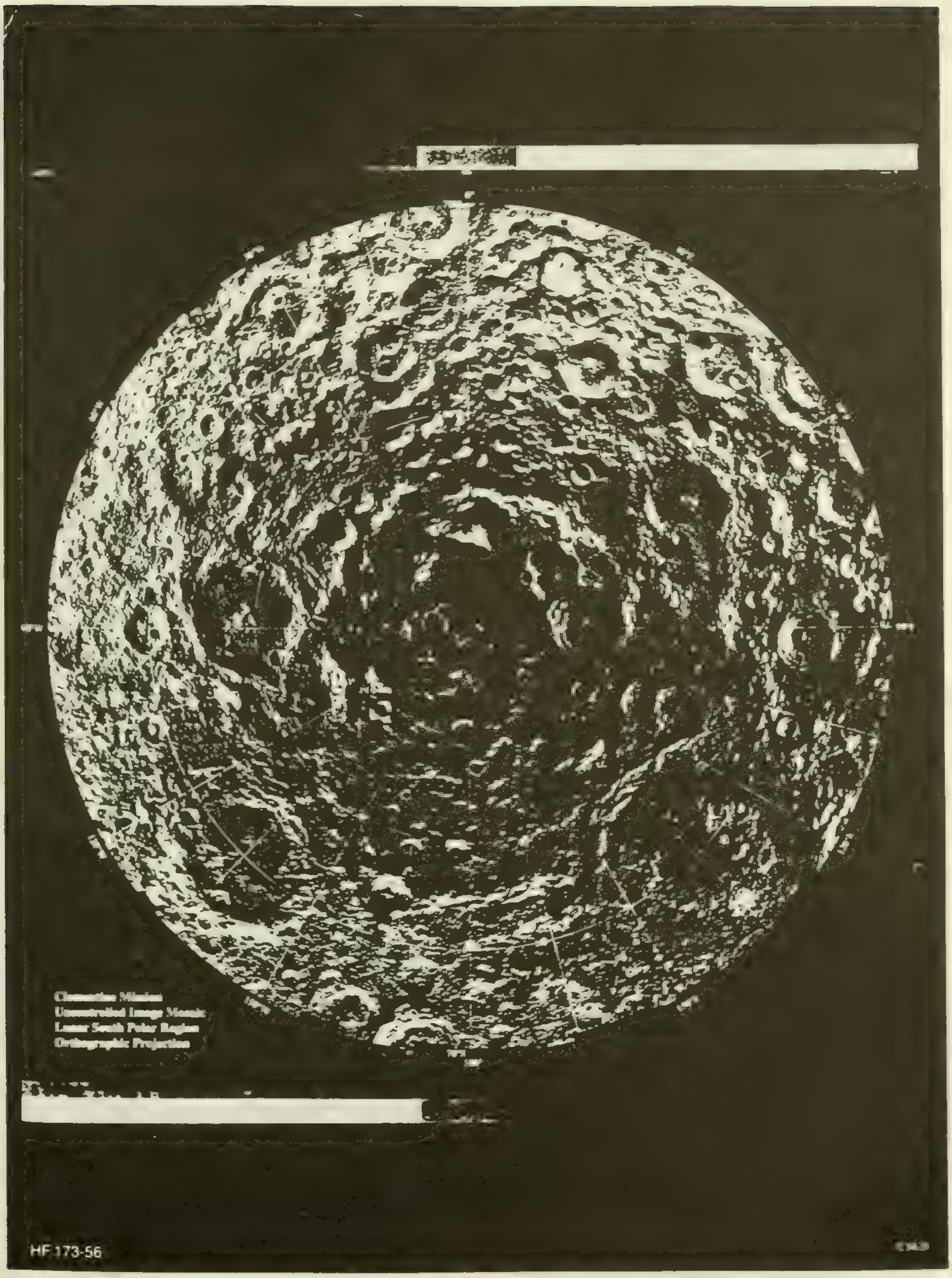
The final result may be that a manned lunar station would be a wonderful source of scientific information both about the Moon and about the universe.

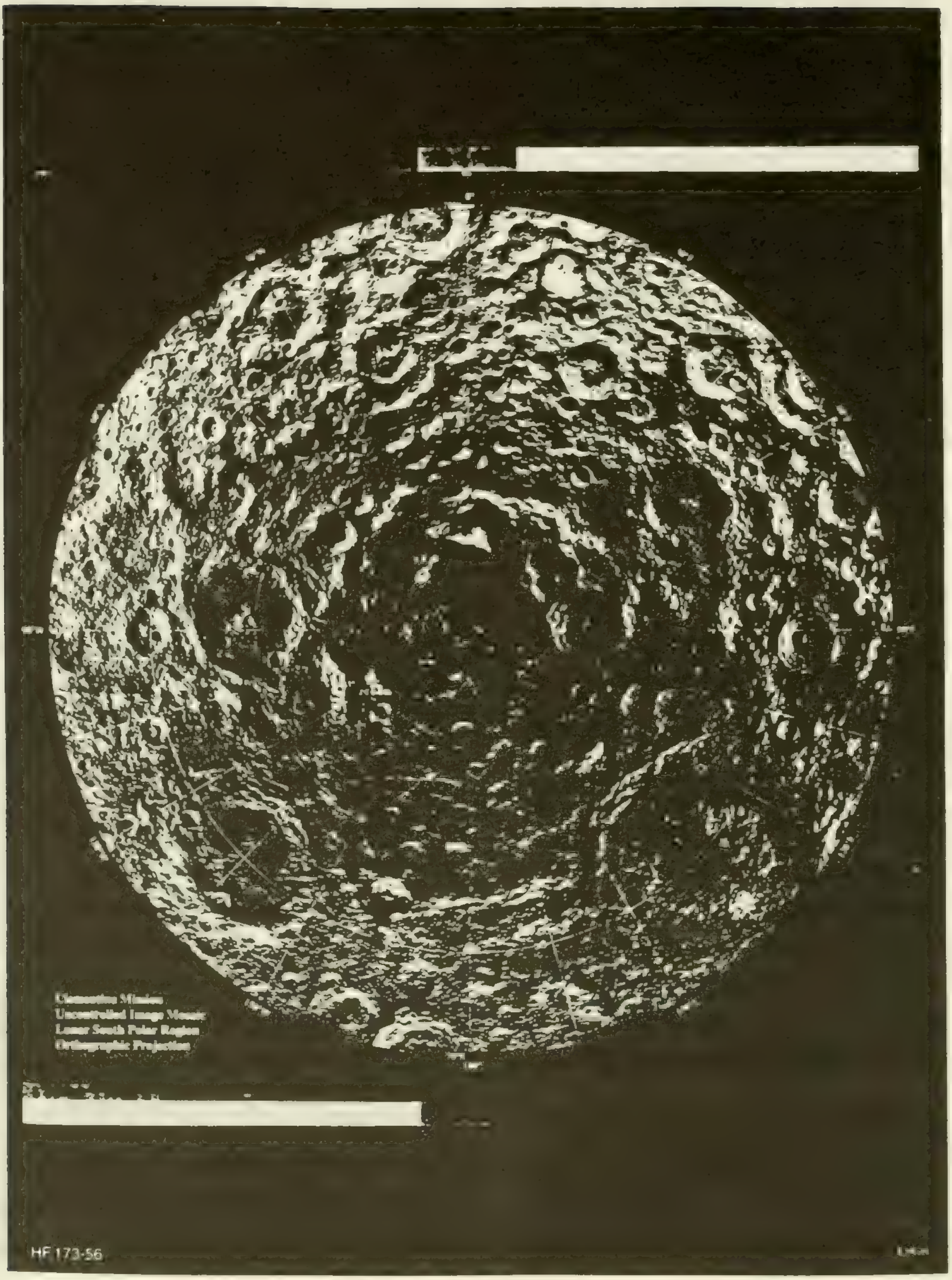
In addition, the Moon may be developed to serve as a refueling station for space exploration. An object launched for distant travel in space carries a lot of fuel and relatively little payload. That, of course, is a powerful reason for the great expense of space exploration.

For launches from the Moon, of course, one need not overcome the large gravitational attraction of the Earth. The chemical fuel we most desire for space travel is available there in its most convenient form: oxygen and hydrogen. Oxygen we can obtain plentifully on the lunar soil and it, of course, accounts for most of the fuel's mass. It is very likely that hydrogen is available as well, either plentifully in the South Polar basin as ice or as deposited by the solar wind at much lower concentration over the whole surface of the Moon. In any case, refueling on or near the surface of the Moon may turn out to be a really practical prospect.

I certainly don't want to belittle the interest of human exploration of Mars. It is highly likely that life cannot be found on Mars at the present time. But on Earth, traces of life are as old as four billion years. It is believed, with good reason, that a similar situation is more probable on Mars than on the Moon. While such early traces of life are most interesting, they are only one of the many things we may find during exploration of many solar system objects. Armed with more knowledge and more high-performance rocket fuel (both obtainable on the Moon), the cost, risk and effort of getting to Mars may be greatly reduced, and the effectiveness of explorations of the whole solar system greatly increased.

Therefore, I recommend at present, let us concentrate on the Moon for less expensive results at an earlier time. With focused international effort commencing soon, a permanent lunar colony could be established in this decade at a total cost well under $10 billion.


Clementine Mission
Uncontrolled Image Mosaic
Lunar South Polar Region
Orthographic Projection
HF 173-56


Clementine Mission
Uncontrolled Image Mosaic
Lunar South Polar Region
Orthographic Projection
HF 173-56

Mr. SENSENBRENNER. Thank you, Dr. Teller. Dr. Charo.

STATEMENT OF ARTHUR CHARO, SENIOR ANALYST, INTERNATIONAL SECURITY AND SPACE PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT, WASHINGTON, D.C.

Mr. CHARO. Thank you, Mr. Chairman. My name is Art Charo. And, I am a Senior Analyst at the Congressional Office of Technology Assessment (OTA).

I am accompanied today by Dr. Ray Williamson, who worked with me on most of the work that I will describe to you.

Mr. Chairman, the ultimate objective of Mission to Planet Earth and U.S. Global Change Research programs is to gain a scientific understanding of global change phenomena sufficient to predict affects on a regional scale. One of the messages I would like to leave with you is that achieving this goal will require decades of continuous calibrated global observations from space and at many sites on the earth's land and oceans.

In my oral testimony, I will highlight three issues. The first is how budget cuts and program downsizing are affecting the EOS; second, how EOS and Mission to Planet Earth might fit into a larger national strategy for earth observation systems; and, finally, how Landsat and future commercial systems can complement each other.

Over the last five years, projected funding for EOS has declined approximately 60 percent. As a result, NASA has been forced to narrow the focus of EOS and Mission to Planet Earth from a broad range of investigations related to global change phenomena to the acquisition of data on just climate change.

The narrower focus leaves the nation more vulnerable to scientific surprises such as the belated discovery of the Antarctic and Arctic ozone holes. And, we feel it also inhibits research into other global change processes.

Despite NASA's best efforts to accommodate budget cuts, the results are an increased risk of gaps developing between measurements currently being performed by NASA's UARS and TOPEX/Poseidon and other satellites and the first flights of EOS. There are excellent scientific reasons to maintain continuity on all these measurements, especially those that require data over long periods to discern subtle trends.

Budget cuts have also constrained funds for airborne and ground-based programs, which both complement and extend the satellite programs, and they've slowed efforts in NASA's small satellite programs. And, finally, the cuts may have had a chilling effect on NASA's capability to undertake technically risky programs that have a potentially high payoff.

Next, I will turn to how EOS might evolve in the future and its relationship to other remote sensing programs. EOS was never intended to be a system that would be maintained indefinitely, in part because of its high cost.

Therefore, a key question for Congress is whether the research instruments being developed for EOS can evolve into the kind of operational instruments that could be sustained for decades. My written testimony addresses several aspects of this difficult question, but here I will stress the connection between this question and a broader one, which is whether the United States would benefit from a more coordinated approach through its many earth remote sensing programs, in part to better manage the development of research instruments and then guide their transition to operational use.

Mr. Chairman, at present, the United States does not have an institutional mechanism to identify national remote sensing interests, nor to prioritize and manage them in a coordinated fashion. In OTA's view, this has contributed to a current situation where we have redundancy in weather satellite systems but no systematic monitoring of the oceans and where Landsat, which has been beset by instability in management and funding, remains vulnerable to a single launch system or spacecraft failure.

OTA believes that a coordinated, multi-agency approach to remote sensing, especially satellite-based remote sensing, could save money while ensuring the creation of a long-term program that would monitor the earth's environmental health in a manner similar as we now do with weather.

Finally, I would like to make a few comments about Landsat and the potential for commercial providers to develop and launch their own service remote sensing systems. As you know, Landsat spacecraft have been in orbit continuously since 1972.

And, the system now serves an established user community that has become dependent on the routine, continuous delivery of data. Rapidly evolving technology may soon enable commercial suppliers to provide Landsat-like data.

But, government could assist the development of this new industry by maintaining consistent, stable remote sensing policies. By not competing with private firms in providing value-added services, government could also assist market development by purchasing data rather than satellite systems from private enterprise.

Even if the commercial systems are extraordinarily successful, geographic data of the quality and scope provided by the Landsat system will still be needed for scientific and applied uses.

In summary, the United States has embarked on an ambitious program of earth remote sensing. Ensuring the success of this effort will require a coordinated federal effort that builds on the expertise resident within individual agencies, in government laboratories, in academia and in the private sector.

Most of all, it will require a recognition by the Administration and the Congress that understanding the mechanisms underlying global change phenomena will require a long-term and stable commitment to a balanced program of research.

Thank you.

[The prepared statement of Arthur Charo follows.]

OTA TESTIMONY

STATEMENT BEFORE THE SUBCOMMITTEE
ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U. S. HOUSE OF REPRESENTATIVES

ART CHARO
SENIOR ANALYST
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OFFICE OF TECHNOLOGY ASSESSMENT

MARCH 16, 1995

Congress of the United States
Office of Technology Assessment
Washington, DC 20510-8025

Testimony of Arthur Charo

Mr. Chairman and members of the Subcommittee, thank you for the invitation to appear at this hearing.

My remarks focus on NASA's Mission to Planet Earth (MTPE) and its most significant component, the Earth Observing System (EOS). While discussing their goals, I will note how these programs fit into a larger national effort to use remotely sensed data to study the Earth; map its surface; monitor its weather; manage its resources, and meet national security needs. I have also appended summaries of a series of reports OTA completed last year that examined the technology, programs, and organization of Earth remote sensing programs.

Mission to Planet Earth is a NASA-initiated concept that uses space- and ground-based measurement systems to provide the scientific basis for determining global change.[1] It is also the central component of the United States' Global Change Research Program (USGCRP), a multiagency effort to monitor, understand, and ultimately predict the nature of global changes and the mechanisms that cause them. The principal goal of MTPE and UGCRP is to increase scientific understanding of Earth as an integrated environmental system and its vulnerability to natural variations and human influences.

The largest single element of MTPE is NASA's Earth Observing System, a series of polar and low-inclination satellites that will be placed in low-Earth orbits beginning in 1998 for 15 or more years of global observations of the atmosphere, oceans, land surface, and biosphere. The currently orbiting UARS and TOPEX/Poseidon satellites are precursors to EOS and part of the first phase of MTPE.

NASA has repeatedly restructured the Earth Observing System to reduce its cost and technical risk. Planned funding has declined approximately 60%, from its original 1989 projection of $17 billion through fiscal year 2000, to the current plan of $7.25 billion. The effect of restructuring has been to increase cost-effectiveness, partly through greater reliance on international partners, and to scale back the scientific goals of the program. In addition, restructuring has constrained funds for airborne and ground-based programs, which both complement and extend the satellite programs, and it has slowed efforts in related NASA small satellite programs.

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[1] Ghassem Asrar and David Jon Dokken, *EOS Reference Handbook*, (Washington, DC: Earth System Support Office, NASA Headquarters, 1993).

NASA's Earth Observing System Data and Information System (EOSDIS), which is planned to manage the enormous data streams that will be acquired daily by EOS, has also undergone restructuring. EOSDIS is now smaller than originally envisioned and program resources are substantially reduced. The importance of EOSDIS to the success of EOS and MTPE cannot be overstated–resolving the myriad of technical challenges related to data storage and archiving, processing, analysis, and distribution to thousands of scientists and other users is essential if the tens of trillions of bytes of raw EOS sensor data that are generated each year are to be transformed into useful information.[2]

Budgetary changes affect at least 3 interrelated aspects of the Mission to Planet Earth that may be of interest to this subcommittee:

1. they alter the scope and balance of Mission to Planet Earth and Earth Observing System programs;

2. they affect the evolution of EOS and its relationship to other remote sensing programs;

3. they increase interest for incorporating the Mission to Planet Earth within a comprehensive national strategy for remote sensing.

The EOS Program

Scope and Balance

As noted above, budgetary cuts have forced MTPE and the EOS program to narrow their scientific focus. Consistent with the U.S. Global Change Research Program,

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[2] In 1990, the amount of data archived from all NASA missions to date totaled some 8 trillion bytes. In 1994, estimates were that EOSDIS would handle approximately 80 trillion bytes of data per year from EOS satellites alone. Other spacecraft tied to EOSDIS might contribute an equal amount of data.

MTPE and EOS are now principally focused on the acquisition of data on global climate. Programs to improve scientific understanding of the middle and upper atmosphere and of solid-Earth geophysics have been deferred or canceled as the budget has shrunk. Plans to develop and orbit important new instruments, such as EOS SAR, a multifrequency and multipolarization synthetic aperture radar that would be similar to that flown on an occasional basis on Shuttle, were also abandoned early on as EOS was downsized. The narrower scientific focus of MTPE and EOS leaves the nation more vulnerable to scientific surprises (the discovery of the Antarctic ozone hole was one such surprise), and it may slow progress in related USGCRP programs designed to increase scientific understanding of important global change processes other than climate, such as changes in biodiversity and forest distributions, desertification, and changes in ocean and coastal ecosystems.

Despite the best efforts of NASA to reschedule missions and make greater use of international partners, the effect of budget cuts has also been to increase the risk of important measurement gaps with the initial phase of MTPE activities, including the measurments of atmospheric chemistry currently being performed by the UARS satellite, the ocean height and circulation measurements currently being performed by TOPEX/Poseidon, measurements of aerosols and ozone through the SAGE instrument, and measurements related to the Earth's thermal balance.[3] Scientists would like continuity in all of these measurements, especially those that require long time series of data to distinguish subtle trends from natural fluctuations.

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[3] The Earth's "radiation budget" consists of incident sunlight minus reflected sunlight (for example, from the tops of clouds) and radiation emitted back to space, primarily from Earth's surface and atmosphere. The emitted radiation falls predominantly in the infrared and far-infrared portion of the electromagnetic spectrum. Earth's average temperature rises or falls to keep the total incoming and outgoing energy equal. Changes in the amount of energy entering or leaving Earth result in global warming or cooling. Clouds regulate the radiative heating of the planet. They cool the Earth by reflecting a large part of the incoming solar radiation; they also warm the Earth because they absorb some of the long-wavelength infrared radiation (emitted by the warmer Earth) as well as emit radiation back to space at the colder temperatures of the cloud tops. A key uncertainty in predictions of future climates is how cloud heating and cooling might change in future atmospheres that are likely to contain a greater abundance of carbon dioxide and other trace greenhouse gases. Options for monitoring Earth's radiation budget are discussed in Appendix B of *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications*, OTA-ISC-558, (Washington, DC: U.S. Government Printing Office, July 1993).

As part of its 1993 report, *Global Change Research and NASA's Earth Observing System*, OTA convened a 2-day meeting of some of the nation's leading atmospheric chemists, public policy experts, and global change researchers, as well as officials, laboratory heads, and scientists from NASA, NSF, DOE, and NOAA (a listing of these participants, and the advisory panel for OTA's overall assessment of Earth Observation Systems, is attached at the end of this statement). This group generally believed that EOS (and by extension, MTPE and USGCRP) science priorities were ordered correctly to gain a predictive understanding of the Earth system. However, several of the participants expressed concern that in accommodating a shrinking budget for EOS, NASA may have overly constrained other science programs that complement and extend EOS. For example, this concern was evident during discussions of certain in-situ measurement programs.

OTA did not ask participants to make judgments about the wisdom of individual instrument selections, nor were participants asked to make comparative judgments about program elements. That exercise, which is currently performed by NASA and its scientific advisory groups, would have taken OTA beyond the terms of reference for its study. However, both supporters and critics of MTPE and EOS voiced strong sentiment that an effective program should provide mechanisms to allow for redirection, substitution, or termination of program elements in light of new discoveries, advances in technology, and changing needs of policymakers. NASA has expressed a similar desire to make the program as flexible as possible; the science community at large now appears more satisfied with the results of NASA's efforts than it did when OTA's report was published.

Sustainability and the Transition from Research to Operational Instruments

The Earth undergoes major processes of change that are reckoned in scales of decades to millennia. Decades of continuous calibrated global observations from space and at strategically located sites on the Earth's land and oceans will be required to document climate and other global changes and to differentiate between natural variability and human-induced changes.

In part because of its high cost, EOS was never intended to be a system that would be maintained indefinitely. Thus, a key issue for Congress is whether the EOS system is an appropriate vehicle to develop the kind of system(s) that would be sustainable for decades. NASA officials expect some research instruments to evolve into the next generation of instruments for routine and long-term collection of environmental data, In particular, the EOS PM series will fly instruments that have potential application for operational weather and climate data collection. Other EOS instruments could become part of a future ocean monitoring system and it is possible that the technologies being demonstrated in advanced surface imagers might find use in designing future generations of Landsat.

The most direct connection between EOS and future environmental monitoring systems is the adaptation of instruments for monitoring weather and climate. This mission is currently carried out by NOAA, which historically has been successful in managing the transition between what were at first research or "experimental" programs to operational programs by adopting a disciplined, conservative approach toward the introduction of new technology.

In addition to lowering technical risk, minimizing cost has been an important factor in the success of NOAA's operational programs. While expressing great interest in EOS technology, NOAA officials have expressed concern about the high cost of flying EOS instruments as part of a system for long-term, routine, data collection. Most likely, operational versions of such key EOS research instruments as MODIS[4] would require redesign to better match NOAA's needs and budget. This raises the obvious question of whether the research instruments on EOS should be designed *a priori* to closely match the expected needs of future operational users. There is no clear answer to this question. In particular, gathering the information necessary to design an instrument most suitable for operational use may sometimes require developing and flight-testing an instrument that in retrospect could have been designed with less capability. In fact, this is the argument scientists at NASA make for their strategy with regard to MODIS.

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[4] MODIS is considered a "keystone" instrument for the EOS program. It is a multispectral instrument for measuring, on a global basis every 1 to 2 days, biological and physical processes on the surface of Earth, in the oceans, and in the lower atmosphere. MODIS may be thought of as a highly advanced, or next-generation, version of NOAA's currently orbiting AVHRR. In addition to having many more spectral bands than AVHRR, MODIS will incorporate extensive on-board "end-to-end" calibration features. These calibration features, which are not present on AVHRR, are designed to give MODIS unprecedented spatial and radiometric accuracy across its spectral bands. As a result, MODIS should be able to distinguish instrument effects from subtle changes in the various processes researchers hope to study.

The OTA report, *Civilian Satellite Remote Sensing: A Strategic Approach*, notes that during the 1960s and 1970s development of NOAA operational weather satellites was assisted by a vigorous R&D program within NASA and by strong ties to several NASA programs, especially Nimbus and OSIP (Operational Satellite Improvement Program). OSIP ended in 1981 as NASA, faced with a tightly constrained budget (in part, the result of Shuttle cost overruns), withdrew from its interagency agreement with NOAA. As discussed below, OTA believes that one of the benefits from a comprehensive national strategy for remote sensing would be to reinvigorate the partnership between NASA and NOAA in the development of civil operational environmental satellites.

A National Strategy for Earth Observations

NASA's remote sensing programs within the Mission to Planet Earth are part of an overall Federal effort to acquire Earth data. It is principally the Department of Defense, the National Oceanic and Atmospheric Administration, the Department of Energy, the National Science Foundation, and the Department of the Interior that carry out this larger effort. The United States also cooperates with other nations to support ongoing programs, especially for monitoring weather.

Private industry is also an essential part of the national remote sensing effort as most spacecraft and instruments are built in the private sector. In addition, industry and government are partners in the management of land resource satellites, and "value-added" companies--firms that develop new data management and processing software to transform raw geospatial data into useful information--are a growing segment of the commercial remote sensing industry. A recent development enabled by technical advances is the possibility that industry will soon begin to market data from privately-operated satellite systems.

In an era of fiscal austerity, obtaining a greater return on investment in space activities has emerged as a key element of national space policy. Until now, new or improved sensors and spacecraft were developed in response to the specific needs of the funding agency. The nation is now re-examining this model, as it considers the risks and benefits of multiagency programs and private sector involvement in providing satellite services.

Greater domestic and international integration could reduce costs, increase the resilience of programs to failure, and lead to fruitful scientific collaborations. However, there are many challenges in realizing these advantages. For example, the federal agencies currently carrying out remote sensing activities have different priorities, respond to different user communities, have different perspectives, and employ different protocols with respect to acquisition and operations. These differences have developed over decades of independent operation and have manifested themselves in numerous ways--most visibly in the different instruments that make up satellite sensor packages.[5] There are also more subtle, but equally important differences.[6] **For these reasons, OTA believes that combining programs such as DoD and NOAA meteorological satellites will be as much a "cultural" problem as a technical and organizational challenge.**

OTA examined possibilities for a flexible, national strategic plan for remote sensing in its 1994 report, *Civilian Satellite Remote Sensing: A Strategic Approach.*
The report noted that global change research is expected to dominate future spending on civil remote sensing systems, and that the need to maximize the return on investments made a national strategy an attractive idea. The elements of such a plan, OTA suggested, should include mechanisms to:

- Guarantee continuity of operational missions--the routine collection of high-quality measurements of weather, climate, and Earth's surface over decades;

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[5] As discussed below, the Administration has directed DoD and NOAA to consolidate their currently separate satellite meteorological programs. Differences in the instruments on board these two systems reflect the different missions and user communities of the two agencies. For example, while NOAA shares a requirement with DoD for cloud imagery, it has a particular need for high-accuracy temperature and moisture profiles of the atmosphere. These data are used to initialize NOAA's twice daily global numerical weather forecasts. DoD's comparatively higher priority for cloud imagery (to meet the needs of classified surveillance programs and the tactical needs of the fighting forces for information about weather) is reflected in its development of a specialized visible and infrared imager not present on the NOAA weather satellites.

[6] For example, DoD and NOAA have particular needs for high resolution microwave imaging and sounding, respectively. DoD's microwave imaging needs are currently met on their meteorological satellite with an instrument known as SSM/I. An upgraded version of SSM/I is also under development by DoD. However, the scanning method used by these instruments differs from the type of scan employed by NOAA sounders. Since NOAA requirements dictate the use of their particular scan method, there would be a problem designing a common DoD-NOAA microwave imager/sounder. **This sensor scan-method mismatch has its roots in the instrument heritage peculiar to NOAA and DoD and may be viewed as an example of the "cultural" difference between the two agencies.**

- Develop a balanced, integrated, long-term program to gather data on global change that includes scientifically critical observations from aircraft and ground-based platforms, as well as space-based platforms;
- Develop appropriate mechanisms for archiving, integrating, and distributing data from many different sources for research and other purposes; and
- Ensure cost savings to the extent possible by incorporating new technologies in system design developed in either private or public sectors.

At present, the United States does not have an institutional mechanism to identify national remote sensing interests, nor to prioritize and manage them in a coordinated fashion. The lack of coordination across Federal agencies has led to redundancy in some systems, for example, there are multiple satellite systems for monitoring weather and climate. However, it has also led to vulnerability in others: a notable example is the Landsat system. Landsat is the United States' principal system for monitoring the Earth's surface. Its budgetary and organizational history can only be characterized as chaotic and it remains vulnerable to a single launch vehicle or spacecraft failure. Similarly, lack of a coherent plan may explain the absence of a system to routinely monitor ocean phenomena and ocean productivity despite their evident importance in understanding global change phenomena and their critical role in commerce. Until the flight of TOPEX/Poseidon, systematic monitoring of the oceans was limited to NOAA and DoD measurements of sea-surface temperature and sea-ice.

Convergence of Meteorological Systems: A Model For A National Strategic Plan?

Recently, the Administration proposed to coordinate several existing environmental satellite remote sensing programs by consolidating ("converging") NOAA and DoD polar-orbiting operational meteorological programs, and capitalizing on NASA experimental remote sensing programs.[7] The Administration has involved NASA in proposals to converge operational meteorology programs for three reasons. First, NASA is funding and developing the EOS satellites, which carry instruments that may later be modified for use on operational weather satellites. Second, NASA currently develops the polar-orbiting weather satellites for NOAA on a reimbursable basis. Third, NASA has historically been the agency that funds, develops, and demonstrates prototype advanced remote sensing technologies for *civil* applications. Once proven, these technologies are candidates for NOAA's operational missions.

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[7] The operational programs are NOAA's polar-orbiting operational environmental satellite program (POES) and DoD's Defense Meteorological Satellite Program (DMSP). The principal NASA program of relevance to the convergence effort is EOS.

However, with its focus on just three federal agencies, and only satellite-based weather and climate monitoring, the convergence proposal is not intended to serve as a comprehensive approach to a broader effort at Earth environmental remote sensing. Convergence of weather satellite programs does, however, illustrate both the risks and benefits of greater agency coordination, and it may serve as a model for further consolidation.

The principal benefit of consolidation of remote sensing systems is the expected reduction in overall system costs. However, in the case of consolidation of weather satellite systems, OTA found that there would be benefits even if there were no cost savings. These include the institutionalization of efficient mechanisms to develop research instruments and to manage their transition to operational use, the institutionalization of long-term (decadal time-scale) environmental monitoring programs, and a strengthening of international partnerships that would facilitate new cooperative remote sensing programs.

The principal risk is disruption in programs that have historically "worked" fairly well in meeting individual agency needs. This risk is particularly acute in operational systems such as the NOAA weather satellites, where data gaps could have severe adverse consequences. OTA's report, *Civilian Satellite Remote Sensing: A Strategic Approach*, details a number of technical challenges to develop satellites that will satisfy both NOAA and DoD operational requirements. However, the principal challenges in implementing a converged system may not be of a technical nature. Instead, they are likely to be:

1. developing effective multiagency management structures that will avoid problems such as those experienced in attempts at shared DoD and NASA management of Landsat;
2. ensuring predicable multiyear funding from the Congress, which would view an integrated joint-agency program only in disaggregate parts unless jurisdictional barriers between authorizing committees and multiple separate appropriations subcommittees were removed. With multiple authorization and appropriations

committees overseeing a joint agency program there is added risk of budgetary disruption.

Surface remote sensing and Landsat

Since 1972, Landsat satellites have imaged most of Earth's surface in several different wavelengths at 80 or 30 meters resolution.[8] Now, after more than two decades of unsuccessful government experimentation to commercialize land remote sensing, the Clinton Administration has decided to return the development and procurement of Landsat to NASA, and has assigned NOAA the responsibility of operating the Landsat system. The U.S. Geological Survey's Earth Resources Observation System (EROS) Data Center will distribute and archive data. NASA plans to launch Landsat 7 in late 1998.

Because a series of Landsat spacecraft have been in orbit continuously, the Landsat system now serves an established user community that has become dependent on the routine, continuous delivery of data. However, the Landsat system is only quasi-operational and has been developed without the redundancy and backups that characterize NOAA's and DoD's operational meteorological programs. As currently structured, the Landsat program is vulnerable to a launch system or spacecraft failure, or instability in management and funding. Notwithstanding the Administration's resolve to continue the Landsat program, the earlier difficulties in maintaining the delivery of data from the Landsat system provide ample warning that the path to a fully operational land remote sensing system is full of obstacles. The United States still lacks a coherent, long-term plan for providing land remote sensing data on an operational basis.

Despite its organizational and funding problems, the Landsat program has been highly successful in demonstrating the potential role that remotely sensed data can assume in the international economy. As the peoples of the world attempt to make better use of Earth's resources, geographic information from satellites will assume an increasingly important role in our daily lives. As a sign of that success, remote sensing has begun to attract significant private investment capital.

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[8] The Advanced Very High Resolution Radiometer (AVHRR) sensors that have been orbited on NOAA's POES satellites have also provided multi-spectral imaging (2 visible channels; 3 infrared channels), but at much lower resolution (1 km and 4 km).

Until recently, overall system costs have been too high to support the commercial collection and sales of raw data. However, commercially-supplied data will soon be available thanks to revolutionary changes in the computer industry; rapidly evolving technology for on-line distribution systems; geographic information systems software, and instrument and spacecraft design; and astute and persistent marketing efforts by data sellers. These data will be of high sharpness compared to Landsat data and will be especially useful for agriculture, land planning, mapping, and resource management.

As noted in OTA's report on *Remotely Sensed Data: Technology, Management, and Markets*, growth of the market for geospatial data will depend primarily on:

- the ability of the marketplace to find additional applications for data from existing systems;
- the distribution of data with higher spectral, spatial, and temporal resolution;
- the development of user friendly software that will enable a wider set of users to apply raw data to new problems;
- the ability of data providers to reach the customer quickly and efficiently after acquiring data; and
- reductions in the costs of providing raw data.

These are the items that the private sector can deal with on its own. But there is a federal role in market development. As the report suggests, Government could assist in reducing industry's financial risks by maintaining consistent, stable remote sensing policies and by not competing with private firms in providing value-added services. Government could also assist market development by purchasing data rather than satellite systems from private enterprise.

Even if the commercial systems are extraordinarily successful, geographic data of the quality and geographic scope provided by the Landsat system will still be needed for scientific and applied uses.[9] Landsat data will continue to provide the geographic anchor for the new, higher resolution data that private firms will market.

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[9] Commercial systems that promise higher spatial resolution than Landsat will not offer Landsat's broad area coverage. With current technology, only Landsat will be able to simultaneously provide multispectral viewing of the Earth over wide area swaths at moderate to high spatial resolution. In the not too distant future, it may be possible to develop a much smaller, lighter, and less expensive version of Landsat. However, the enabling technologies for such a system are generally considered too immature for incorporation in the next Landsat, or any other system that has an operational requirement. See discussion of Landsat in Appendix B of *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications*, OTA-ISC-558, (Washington, DC: U.S. Government Printing Office, July 1993).

OTA Publications on Remote Sensing of the Earth

Reports:

- *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications,* OTA-ISC-558, (Washington, DC: U.S. Government Printing Office, July 1993).

- *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1994).

- *Civilian Satellite Remote Sensing: A Strategic Approach*, OTA-ISS-607 (Washington, DC: U.S. Government Printing Office, September 1994).

Background Papers:

- *Remotely Sensed Data from Space: Distribution, Pricing, and Applications* (Washington, DC: Office of Technology Assessment, July 1992).

- *Data Format Standards for Civilian Remote Sensing Satellites* (Washington, DC: Office of Technology Assessment, April 1993).

- *The U.S. Global Change Research Program and NASA's Earth Observing System,* OTA-BP-ISC-122 (Washington, DC: U.S. Government Printing Office, November 1993).

Requesting Committees:

House of Representatives:

Committee on Appropriations (Subcommittee on Veteran's Affairs, Housing and Urban Development, and Independent Agencies)
Committee on Science
Permanent Select Committee on Intelligence

Senate:

Committee on Appropriations (Subcommittee on Veteran's Affairs, Housing and Urban Development, and Independent Agencies)
Committee on Armed Services
Committee on Commerce, Science, and Transportation
Committee on Environment and Public Works

Mr. SENSENBRENNER. Thank you very much. Before getting to questions, the Chair would like to advise the members of the Subcommittee that the time for amendments on the rescission bill that is being debated in the House ends at 12:18.

And, the Chair greatly fears that if we don't get to the sixth and final panel before that, nobody will come back after lunch, whether it's witnesses or members of the Subcommittee. So, with that in mind, the gentleman from Kansas, Mr. Tiahrt, is recognized for questions.

Mr. TIAHRT. I have a question for Mr. Brock. I spent almost 14 years in the aerospace industry and survived several government audits, multiple government audits, so it's always fascinating to me when the government audits itself.

And, I wondered, in your observation of the downsizing of EOS, have they readjusted the requirements sufficiently enough to match the downsizing?

Mr. BROCK. Right now, we are not prepared to answer that. We are right in the middle of a study.

We have a larger scale study being done at the request of Chairman Walker to look at that very question, among others. Our initial focus on this assignment was to look at the EOSDIS program.

But, we are developing an answer to your question. Unfortunately, the answer is several months away.

Mr. SENSENBRENNER. If the gentleman will suspend, I would like to poll the members of the Committee who are present. This is a live quorum in Committee and the five minute vote following.

That means that the earliest we will be able to come back is probably five minutes after 12. And, we will then have more votes at 12:18 and probably not be able to return until after one o'clock.

What I would like to do is to have the questions for this panel conclude by 12:18. And, then we will come back.

Let's set a meeting time for coming back for the sixth panel at 1:15. Does that meet with the agreement of members of the Committee?

How many more questions does the gentleman from Kansas have? Okay.

The gentleman from Kansas is recognized. And, at the conclusion of the gentleman from Kansas' question, the Committee is in recess until approximately 12:05.

Mr. TIAHRT. I guess what I would like to ask is that we are in the process of downsizing other portions of the government. And, I think there may be lessons to learn that NASA is going through now.

It's very painful. It is happening in private industry. If there—are you in the process of documenting this downsizing and how it impacts programs?

And, are there lessons learned that you could pass on to other parts of government as they experience a similar downsizing?

Mr. BROCK. Not only are we looking at NASA, we are looking at a number of agencies and the effects of downsizing and what you have to do. I mean, a critical lesson, I think, right now relates directly to my testimony, though.

If NASA is downsizing, it makes it even more critical that it understand its users, its audience, its customers and how they want to use data and how that can best be served and then have a development strategy for its systems that will, in fact, meet those needs. That's critical at any level of funding.

But, it's increasingly critical when you are getting smaller. They can't afford to make a lot of mistakes.

Mr. TELLER. I am done. Thank you. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The Committee is in recess until about 12:05.

[Whereupon, a recess is taken at 11:40 a.m., to reconvene at 12:04 p.m., this same date.]

Mr. SENSENBRENNER. The Subcommittee will come to order.

The Chair sees no members waiting to ask questions. So, let me thank you all for waiting around.

Thank you for coming to testify today. As I've said after the previous panels have concluded their testimony, members are entitled to ask written questions within a week after the hearing date. And, we would appreciate your responding within a week to 10 days after receipt so that we can get the hearing record complete and off to the printers.

Yes, Dr. Barron?

Mr. BARRON. I have been on travel. And, I wonder if I can still have the opportunity to submit written comments for the record.

Mr. SENSENBRENNER. Certainly, you may. Please get the written comments in as soon as possible, because again we do not wish to delay the publication of the hearing record indefinitely.

Mr. BARRON. Thank you.

Mr. SENSENBRENNER. So, thank you all for coming. And, the Subcommittee will be in recess until—

Mr. TELLER. Mr. Chairman—

Mr. SENSENBRENNER. Yes, Dr. Teller.

Mr. TELLER. —there is one topic I was very anxious to cover. I have a short—if I can give it now, not more than three minutes I can do it.

Mr. SENSENBRENNER. The gentleman is recognized.

Mr. TELLER. Of the many problems that we discussed, for brevity, I omitted one which I consider important to mention it now. We now know from recent events, statistics, a lot of work that the chance of collision of the earth with an astroid is not negligible. Something like a 10 percent chance within our lifetime of a truly major, billion—order of magnitude, billion dollar damage, a chance of a much bigger disasters in a million years.

But, the amount that one could spend on it in a reasonable way as insurance I believe is reasonably in the order of maybe 100 million dollars a year. And, for that amount, we can do two things reliably.

One is underway. The other is not. The one that is underway, our observations, which will definitely predict any such collision at least a couple of months in advance, quite possible 10 years in advance.

If such a collision is predicted as has occurred on Jupiter recently, it can be prevented because we now know how to transport the appropriate amounts of energy into space. And, the object could be either deflected or exploded and the problem avoided.

But, this cannot be done on calculations alone. Previous, relatively inexpensive experimentation is needed.

And, I think a little part of the attention of NASA should be directed toward that.

Thank you, Mr. Chairman.

Mr. SENSENBRENNER. Thank you, Dr. Teller. The gentleman from Florida, Dr. Weldon.

Mr. WELDON. Thank you, Mr. Chairman. Mr. Brock, I have some questions regarding the EOSDIS.

Has anybody looked at or, you know, what is currently known about the potential size and the makeup of the user community for the information?

And, is it reasonable to assume that some of those users will have little technical knowledge?

And, is that being taken into consideration in terms of the design of the impact of the EOSDIS?

Mr. BROCK. Most of the user requirements, Mr. Weldon, are largely focused on the principal investigators, 500 or so, plus some other NASA employees. These are largely directly funded by NASA.

The large scale universe of earth scientists that are not affiliated, about 10 thousand or so, their needs have not really been solicited by NASA and are not really accounted for. The general public who might use it—and NASA, I guess, threw out some estimates of a couple hundred thousand on this—farmers, businessmen, et cetera, people that had a general interest in the information who have very limited technical expertise in accessing the data, have really not been accounted for at all.

So, NASA has really focused its user requirements on a very small but a very important subset of the user universe.

Mr. WELDON. Has there been any consideration of having another entity besides NASA handle the data itself?

Mr. BROCK. Well, a lot of the data will be handled by the data centers themselves. So, the scientists will have more direct access.

And, in fact, the National Research Council recommended that these eight data centers have more input into developing the requirements for the NASA systems, because they were more closely associated with the scientists and the scientific community that would be using—would be a large part of the user base for EOSDIS.

Mr. WELDON. A question for Dr. Anderson and Dr. Charo.

I noted that in some of the early components of the Mission to Planet Earth there is some international involvement, but it seems to be somewhat limited. But, yet the impact of all the information that we are having or that potentially will be collected has a tremendous amount of global interest.

I am wondering if we should be pursing some more international involvement?

There has been mention made by at least one member of the panel here about how this program has been consistently downsized over the past few budget cycles. And, would it not be reasonable to actually achieve some of the original intended goals of the program with more international involvement as opposed to just relying on the United States taxpayer to pick up the tab for this?

Mr. CHARO. Actually, one of the results of the downsizing has been an increase in international involvement or, more importantly, the dependence on international partners to provide certain instruments and perform certain measurements. And, you can view that either as an opportunity or as a risk.

Historically, international partners have done very well in fulfilling their end of the bargain and in providing measurements that they sign up for. But, NASA, in fact, to try to cover some of the gaps that have been created in the downsizing is working very hard to work in an international angle.

There are other things in our study that I didn't mention, even in my written testimony, that you might imagine doing in the international arena. But, specifically on EOS, I know from briefings from NASA and from studying the program that I think they are working that angle very hard.

Mr. ANDERSON. I think that's a very good question. The small system flexibility that is being worked on, which involves small satellites and remotely piloted aircraft provide a tremendous opportunity not only to engage the scientific community around the world but also to engage that scientific community with their political process, because until they achieve scientific breakthroughs in certain areas they have difficulty communicating with their political system.

I mean, a hearing such as this we take for granted. It's the way we exchange information.

But, that's the exception and not the rule internationally. And, I think one of the crucial things about NASA's approach to smaller and quicker approaches is to open up the ability to make observations to the international community.

That, of course, cuts both ways. I think this question of the high speed civil transport focuses the need to bring the leadership that this nation has on diagnosing the stratospheric condition with the leading aerospace designs for this aircraft in a way that should bring international leadership if it's used properly.

Mr. SENSENBRENNER. The time of the gentleman has expired. The gentlewoman from Texas, Ms. Jackson Lee.

Ms. LEE. Mr. Chairman, I thank you very much. And, first, let me offer my deep appreciation for the presentation of the panel and certainly acknowledge the leadership of Dr. Teller and all that he has given to the areas of study of which he has just spoken.

Let me ask Dr. Barron, if you would, as I understand it, when we begin to talk about the question of restructuring and downsizing if there has ever been a particular program that has seen its share of it, its Mission to Planet Earth, going from some $17 billion to $7.25 billion?

I would imagine, in the course of that, there has been a sharp decline in the ability to do certain types of research but, more importantly, I would hope and I would expect that there was certainly a wide degree of restructuring and refocusing in terms of the kind of resources that were available.

I would like, if you would, Dr. Barron—and I know in your presentation you gave some of that—if you could give us a pithy explanation of the scientific rationale for Mission to Planet Earth.

One of the difficulties we have in encountering what we will encounter in the next couple of months, budget and then appropriations—right now, I keep reminding everyone in rescissions which include certainly some aspects of what NASA is doing—is explaining or convincing. And, I think it's more convincing the public sentiment than maybe even some of the members of Congress who seem to be so driven by public sentiment.

So, if you would, I would appreciate that kind of pithy analysis. And, maybe you can also tell me what extremes the program would have to go to if further downsizing would occur, what further restructuring?

And, I thank you very much for being here this morning.

Mr. BARRON. Okay. Thank you. We have gone through a tremendous downsizing and restructuring every year, I think, for four straight years.

And, what we've seen is much greater dependence on foreign partners. Almost all of the satellites we are talking about have foreign instruments.

We are trading in terms of their platforms. The Science Executive Committee, a set of scientists involved in EOS, are about to meet with the European Space Agency scientists to discuss this cooperation and where there can be overlaps and mutual benefits.

We've lost things. Almost all of the people that have been involved in it are working with less money.

We've put a lot of things on the table with increased risk. We are not sure whether we are actually going to get the measurements.

We've gone through enough downsizing that right now any further budget cuts means that you are going to take critical science questions and you are just not going to be able to address them at all, because there is no more room in terms of those issues. The interesting thing about it is that in all of this downsizing and all of this loss of money and all of the scientists taking less and less, not once have we proposed that we delay the launch of the EO satellites.

We have sat there fixed with that launch coming up in a couple of years. And, this goes right to your question, because what it suggests to you is that the scientists feel that we have a sense of urgency here in terms of what the environmental climate/ecosystem impacts are going to be, because we are changing the chemistry of the atmosphere, because we are modifying the surface of the earth and, in particular, because of greenhouse gases.

The models that we have that make predictions for what may happen suggest rather dramatic changes. We need to make sure—we need to address all the critical science questions that limit how good those predictions are so that we can do a better job.

That's the entire reason to have a Mission to Planet Earth—monitor those changes so that we can see them coming, increase our ability to predict the future so that we can limit the cost of adapting to those changes in terms of cost to national security, in terms of cost to economic vitality because of the impact on water resources and agriculture and ecosystems.

Ms. LEE. You have just highlighted it. And, just, if I can get you to, even in more details, give the human impact.

You've said agriculture. You've said economics. If you can, give maybe an example of how that literally translates to everyday life.

And, interestingly enough, if that launch is on schedule or target, it's interesting that we would not want to make sure that the data is there. But, if you would, point to maybe some human specifics.

Mr. BARRON. You can take a lot of different examples. Water—the water balance—the reason why I showed precipitation, the water balance that is predicted to change is very large. Now, you go pick a country, say, behind the former Iron Curtain where now you have water rationing where every three days you get to have some drinking water.

That's going to have an impact on things like migration of people. And, this is especially going to impact countries that are not as developed as the U.S.

Or, you can take the case of the 1988 drought and what its impact was in terms of agriculture in this country. It far exceeded a billion dollars.

You can think about predictions from Elniño and see that by predicting Elniño in advance we can—you can actually save a considerable amount of money and you can predict your agriculture and protect some of your water reservoirs in advance.

Ms. LEE. Thank you.

Mr. SENSENBRENNER. Time of the gentlewoman has expired. The gentlewoman from California, Ms. Harman.

Ms. HARMAN. Thank you, Mr. Chairman. First, I would like to commend you and staff for putting together this mega hearing in the way you have and for preparing the materials that you have.

It's very, very useful to a second term member. I know much more about NASA than I did last term. So, thank you.

Secondly, I want to say to the panel that the testimony on this issue was very helpful. And, to you, Dr. Teller, the picture you brought of the moon is enormously exciting. And, it gives all of us an appreciation of what NASA's space science programs really can achieve.

My question is this. We've spent a lot of time in the Science Committee talking about risk assessment. And, as I'm sure you all know, a risk assessment bill has passed the House and is now pending in the Senate.

What can this subject, the Mission to Planet Earth subject, contribute to the scientific basis for risk assessment in the future?

And, if you could be as specific as possible, I would appreciate it. And, any of you are welcome to answer this.

Mr. TELLER. Yes.

Ms. HARMAN. Dr. Teller.

Mr. TELLER. The question is specifically what a mission to the moon could contribute to risk assessment?

Ms. HARMAN. No, no. What can earth orbiting stations and the Mission to Planet Earth contribute to risk assessment?

Mr. TELLER. I believe that every operation carried out in the proper way will contribute. The point I am making, however, is that we should, we can, decrease the risk, in this case, to practically zero but at the same time, also decreasing the cost in a really dramatic fashion.

The present plans to do EOS in a manned expedition will cost many times the billion dollars a year that the unmanned expedition will cost. And, I believe that here a careful reevaluation between manned and unmanned expedition is called for which unfortunately, in this meeting, I did not hear emphasized.

I tried to bring in the question about the moon to show that there are cases where man is needed, where risk will not be completely avoided although it can be minimized. In the case of the earth, a manned expedition will mean risk, not great risk but does mean a lot of money.

And, I would like strongly to urge even more attention on the unmanned small objects, because that could result in multibillion dollar savings.

Ms. HARMAN. Thank you. Others? Yes?

Mr. BARRON. Well, I would just say that, from my particular viewpoint, to enhance risk assessment, the things you want to know are: One, what is the impact? What's going to change?

And, the second thing you want to know is: Are you vulnerable to those changes?

And, you could take an example of high rainfall in the State of California due to Alnenyo variations, something the Earth Observing System and Mission to Planet Earth undoubtedly will provide the observations that give us some of that advance warning by seeing how the system is changing and by enhancing our ability to predict those changes. And, if you can enhance that ability to predict and you can tell what is happening, then you can sit and make a rational decision on whether you are vulnerable to those changes in rainfall or whatever else.

And, that's where I think that it makes a real contribution to risk assessment.

Ms. HARMAN. Thank you. Yes, Dr. Anderson.

Mr. ANDERSON. I would like to focus on the high speed civil transport. The prototype has to go into development in 1998.

And, I have presented two examples here of very rapid response systems that answered questions unequivocally. And, I have to focus on the unequivocal nature of the results, because decisions have to be made on those.

And, I would stress, again, that the unmanned component must be looked at. We need both a microscope and a telescope to study this problem.

Ms. HARMAN. Thank you, Mr. Chairman.

Mr. SENSENBRENNER. The time of the gentlewoman has expired.

Once again, I would like to thank the members of the panel for their very good testimony.

The Subcommittee is recessed until 1:15, at which time we will hear the testimony from Panel 6.

[Whereupon, a recess is taken at 12:25 p.m., to reconvene at 1:21 p.m., this same date.]

Mr. SENSENBRENNER. The Subcommittee will be in order.

First, let me thank the sixth and last panel for their patience. I think we've got about 45 minutes of peace and quiet for some testimony and some questions and answers.

On the sixth panel are Dr. Francis Everitt of the Gravity Probe B Office of the Hansen Experimental Physics Lab at Stanford University, California; Dr. William Boynton, Chairman of the Space Science Working Group of the University of Arizona at Tucson; Dr. Dan Lester of the Department of Astronomy at the University of Texas at Austin; and, David Gump, President and CEO of Luna Corporation in Arlington, Virginia.

All of your prepared statements will be placed into the record. I would ask that you summarize them in about five minutes.

And, I will recognize Dr. Everitt first.

STATEMENT OF FRANCIS EVERITT, GRAVITY PROBE B OFFICE, HANSEN EXPERIMENTAL PHYSICS LAB, STANFORD UNIVERSITY, STANFORD, CALIFORNIA.

Mr. EVERITT. Thank you, Mr. Chairman and members. I am here to tell you something about the Gravity Probe B mission, which is an on-going mission. In fact, approximately half way through and is building flight hardware.

Now, the Gravity Probe B mission was invented and we are practicing it to test Einstein's general theory of relativity.

When we recall that this theory was proposed eighty years ago, and still necessary to test, that may seem very surprising, but one of the reasons why is that space has given unique opportunities for testing this theory which is one of the most fundamental theories in physics, and is also a theory which Einstein himself knew wasn't in all respects the final answer.

I will not attempt in detail, Mr. Chairman, to give you all the technical subtleties of Einstein's theory, but we are going to measure a very fundamental aspect of it, which is that rotating matter drags space and time around with it.

And if I may refer to something that is in my written testimony, which I will not read, Professor Frank Yang, who is probably the most distinguished living theoretical physicist, has stated that this makes the experiment, Gravity Probe B, an especially crucial and important test of what Einstein is doing.

We are also making other measurements which I can, perhaps, refer to and answer questions if necessary.

Now, Gravity Probe B has had a very interesting history, somewhat of a complicated history, as a result of which in 1985 NASA began a program called STORE, which was originally intended to fly on the shuttle, and various events prevented that happening, which resulted in building flight hardware. And in the last few months we have taken delivery of one of our two final flight instruments for Gravity Probe B.

And I am glad to say that the program is, in fact, ten months ahead of schedule.

We are in the midst of testing this new hardware and meanwhile the National Academy of Sciences has been asked to undertake a new review of the program and we have been very impressed with that review. And the questions that we have asked, I think, will be interesting in a process where Gravity Probe B is in a somewhat unusual situation in the budget to see the response of the Committee. And I look forward with some confidence to that.

Let me say one other thing about Gravity Probe B, which is the remarkable role that students have been able to play in this.

Over the years of a very long, inventive development of this experiment involving new technologies, we have had a total of approximately two hundred and fifty students.

People are sometimes surprised that it is possible in a long-term mission to get creative work out of students. The reason is that they have been part of the sophisticated invention process of this entire mission, and this is an important, and to my way a beautiful thing, to have the pleasure of having and watching students invent part of a flight program.

So, the mission is managed by NASA Marshall Center. Another feature of it that I think is interesting, is the very innovative management process that has been put in place by NASA, Sanford and industry and Mr. Chairman, I think I will leave it at that.

Thank you.

[The prepared statement of C. W. Francis Everitt follows.]

GRAVITY PROBE B RELATIVITY MISSION

Testimony of

C. W. Francis Everitt

Principal Investigator, GP-B

Stanford University

before

Committee on Science

Subcommittee on Space and Aeronautics

March 16, 1995

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TESTIMONY OF C. W. FRANCIS EVERITT

PRINCIPAL INVESTIGATOR, GRAVITY PROBE B RELATIVITY MISSION
W. W. HANSEN EXPERIMENTAL PHYSICS LABORATORY
STANFORD UNIVERSITY

BEFORE THE SCIENCE COMMITTEE
SUBCOMMITTEE ON SPACE AND AERONAUTICS
U. S. HOUSE OF REPRESENTATIVES

MARCH 16, 1995

Mr. Chairman, Mr. Hall, Honorable Members may I first thank you and the full Science Committee for your unwavering support of peer-reviewed science. I come before you to testify about NASA's Gravity Probe B Relativity Mission. Gravity Probe B has been strongly endorsed in many in-depth reviews including no fewer than three National Research Council Reports: the Shapiro Report "Strategy for Gravitational Physics in the 1980s" (Space Studies Board 1982), the Brinkman Report "Physics Through the 1990s" (Board on Physics and Astronomy 1986), and the Donahue Report "Space Science in the Twenty-First Century" (Space Studies Board 1989). Now, at NASA's request our program is going through yet another NRC review chaired by Professor Val Fitch of Princeton University. We have been impressed by the depth of many of the questions received in this latest review and believe that it too will serve an important constructive purpose.

Development of prototype and preprototype flight instrument hardware for Gravity Probe B commenced in 1985 by Stanford University with a subcontract to Lockheed Missiles and Space Company, following a decision by the then NASA Administrator Mr. James Beggs. Development of the spacecraft was initiated in 1993 following a decision by the current Administrator Mr. Daniel Goldin. We are grateful to Mr. Beggs and Mr. Goldin for their supportive actions. In the accompanying documentation submitted with this testimony are photographs of completed major elements of the flight hardware described in more detail below.

The Importance of Gravity Probe B

Gravity Probe B is a new experiment in fundamental physics which cannot be performed in any other way except by using the extremely quiet environment of space. It tests in new ways, and with unexampled precision, Einstein's theory of gravity, usually known as his theory of general relativity. The mission will also perform, as a coexperiment, new very much more exact measurements of the shape of the Earth that will have surprising practical significance in our study of the oceans and the atmosphere.

Einstein's theory of general relativity is the theory we currently use as the basis for our understanding of the large-scale structure of the Universe. Questions about the curvature of space-time; the expansion of the Universe, whether the Universe is closed or open, whether gravitation propagates in waves, questions about the nature of those mysterious bodies called "black holes," all go back to this theory that Albert Einstein, the man of peace, conceived eighty years ago during the darkest days of World War I.

Why, it may be asked, do we need to test a theory that has been accepted and used for eighty years and one that connects with the magical name of Einstein? Surely it must have been sufficiently proved by now.

The answer is absolutely Einstein's theory needs to be checked for at least three reasons. First, some of its most fundamental predictions have never been verified. Second, we know (and Einstein knew) that at some level his theory was wrong — or at least incomplete. It cannot be reconciled with quantum mechanics (our theory of the atom), and it only half-achieves Einstein's program of reducing all physical forces to geometrical concepts. Third, we have the extraordinary example of Newton's earlier theory which Einstein's theory replaced. For over 200 years after Newton invented his theory, it progressively explained more and more facts about the Universe and about ordinary life. Then, one simple observation, a subtle error in the motion of the planet Mercury undermined Newton's intellectual structure and made way for Einsten's quite different one.

Science progresses by experimentation, either by measuring known effects much more precisely or by exploring new effects. Gravity Probe B does both. It will test one aspect of Einstein's theory — the curvature

of space — far more exactly than ever before. And it will test a completely unverified aspect of the theory, the mysterious phenomenon known as *frame-dragging*: a twisting action on space and time exerted by a spinning body such as the Earth. The distinguished Nobel Laureate C. N. Yang, of SUNY at Stony Brook, has written:

> ***Einstein's General Relativity theory, though profoundly beautiful, is likely to be amended ... that the amendment may not disturb the usual tests is easy to imagine, since the usual tests do not relate to spin. The proposed Stanford experiment is especially interesting in that it focuses on the spin. I would not be surprised at all if it gives a result in disagreement with Einstein's theory.***

For further insight into the importance of Gravity Probe B may I refer you, Mr. Chairman, to letters by two very eminent relativists Professor Irwin Shapiro, Director of Harvard University SAO, and Professor Kip Thorne, of Caltech, recently sent to the Chairman of the full Committee Mr. Robert Walker.

How Does Gravity Probe B Work? The Role of Space

At the heart of the Gravity Probe B instrument are four exquisitely precise *gyroscopes* — that is to say small spinning bodies that provide a very accurate reference for directions in space. The development of gyroscope technologies of various kinds has been one of the heroic technological achievements of the last fifty years, essential to the military and essential also in the safe navigation of ships and airplanes.

Because of their design and the fact that they operate in space the Gravity Probe B gyroscopes provide a reference *more than a million times more accurate than any existing gyroscopes.*

In construction these gyroscopes are spheres 1.5 inches in diameter (the size of a ping pong ball) made of a special kind of glass known as fused silica, polished round to better than a millionth of an inch and coated with a thin layer of a superconducting metal. They are the roundest objects in the known Universe. These spheres are electrically suspended in a spherical cavity at very high vacuum. They are spun to 10,000 rpm and their direction of spin is measured with very great precision by means of a magnetic sensor operating at a very low temperature, known as a SQUID (Superconducting QUantum Interference Device).

Four gyroscopes provide four entirely independent tests of the two Einstein effects described above. The gyroscopes are mounted in a quartz block to which is attached also a telescope of very novel design capable of measuring angles as fine as one ten-thousandth of an arc-second (the width of a human hair seen at a distance of 100 miles). The experiment consists in measuring to that precision small predicted changes in direction of the gyroscopes with respect to the line of sight to a suitable well measured guide star. The twisting action of space will be checked to better than 1 per cent and the curving action of matter on space to a few parts in 100,000.

The gyro-telescope structure is enclosed in a "dewar vessel" (thermos bottle) which operates at a temperature 1.8 degrees above absolute zero and stays cold for 18 months. During that time the spacecraft rolls slowly (once every three minutes) around the line of sight to the star, and is pointed precisely by means of thrusters making use of the helium gas escaping from the dewar. The same thrusters also allow compensation of the residual air drag on the spacecraft by applying a compensating push referenced to one of the gyroscopes.

Within Cost, Ahead of Schedule

Gravity Probe B is at present approximately half way through its planned development and expenditure cycle. Construction of flight hardware is well in hand, with hardware elements listed below already delivered to Stanford. As of the end of FY 1995 a total of $236 M will have been spent. 'Costs-to-go' for the target launch date of December 1999 are $235 M. We are currently 10 months ahead of the schedule required to meet this launch date. NASA in its overall planning budget is allowing an additional 10-month margin to its mandated launch date of October 2000. Further details on costs are available in the supporting documentation provided with this testimony. The launch vehicle (not included) is a Delta II at $50 - 60 M.

All elements of flight hardware for the GP-B instrument have been prototyped, and many of the final parts are at or close to completion. After 100,000 hours of testing of flight prototype gyroscopes, we are now completing construction of the final ones at Stanford. The containing structure for one of the two flight instrument assemblies was delivered by Lockheed to Stanford in August 1994. Installation of a prototype gyro-telescope assembly into this structure was completed in February 1995. Full-scale testing will begin in April 1995. A prototype flight telescope has already been extensively tested. Construction of the first of two flight versions commences in June 1995 for delivery to Stanford in December 1995. The main tank of the flight dewar vessel was completed in January 1995 and successfully passed its critical high vacuum test in February. Key spacecraft components have also been prototyped. (Illustrations of these flight systems are available in the supporting documentation.)

Interdisciplinary Invention, Incremental Prototyping and the 'Management Experiment'

Gravity Probe B is an experiment that crosses intellectual boundaries and combines ideas from many different disciplines. Space is essential to it, so are refined techniques from low temperature physics, so is sophisticated spacecraft control technology. From the beginning the experiment was planned as a joint venture between the Stanford Departments of Physics and of Aeronautics and Astronautics. Subsequently, the collaboration has widened to include expertises at the University of Alabama, Huntsville; Harvard SAO, and the Universities of Ohio and Maryland, to give examples of just a few institutions nationwide that contribute. The single name for all this progress is interdisciplinary invention.

As far back as 1980, it was clearly seen that an even more critical issue would be to find the right way of combining the University research team at Stanford with aerospace industry. The pivotal Rosendhal Report "Assessment of the State of the Technology Development of the Stanford Gyro Relativity Experiment" (September 1980) spoke of the critical importance of continuing "*the remarkable technological accomplishment of the dedicated Stanford experiment team .... with a strong engineering team in a flight development program.*" After intensive discussions between NASA Headquarters, NASA Marshall Center, Stanford University, industry and experienced members of the scientific community, a somewhat unusual but appropriate arrangement was set up in 1984 which was dubbed by the then NASA Administrator, Mr. Beggs the "GP-B Management Experiment."

The Management Experiment has incorporated ideas special to Gravity Probe B with management techniques in other advanced programs, for example the Lockheed "Skunkworks." It has pioneered three methods that have been increasingly seen in recent years to be beneficial in many NASA programs.

(1) Oversight at the NASA Center by a small but highly qualified centralized team with close insight into the program but with significantly reduced (though sufficient) reporting requirements. NASA Marshall Center has taken a pioneering role in this process.

(2) Management of the Aerospace Contractor (Lockheed) by a University (Stanford) in a collaboration that combines exceptionally close technical cooperation at the working level with flexible and innovative procurement strategies. Features of the technical management include strong downward delegation to responsible product development teams. Features of the procurement strategy include skillful use of the award fee and a method of special tasks that minimize danger of experiencing costly change orders.

(3) A process of Incremental Prototyping which concentrates early on hardware development in key areas where negotiations are addressed and solved early on with small dedicated teams before the advent of the "marching army" of the spacecraft development.

A measure of the success of the Management Experiment to date is that despite many changes, cutbacks and surprises in the budgeting process, the foreseen runout cost of Gravity Probe B remains (after adjustment to real year dollars) identical with the prediction made by NASA Marshall Center at the completion of its 1982 Phase B Study.

The Role of Students in Interdisciplinary Invention

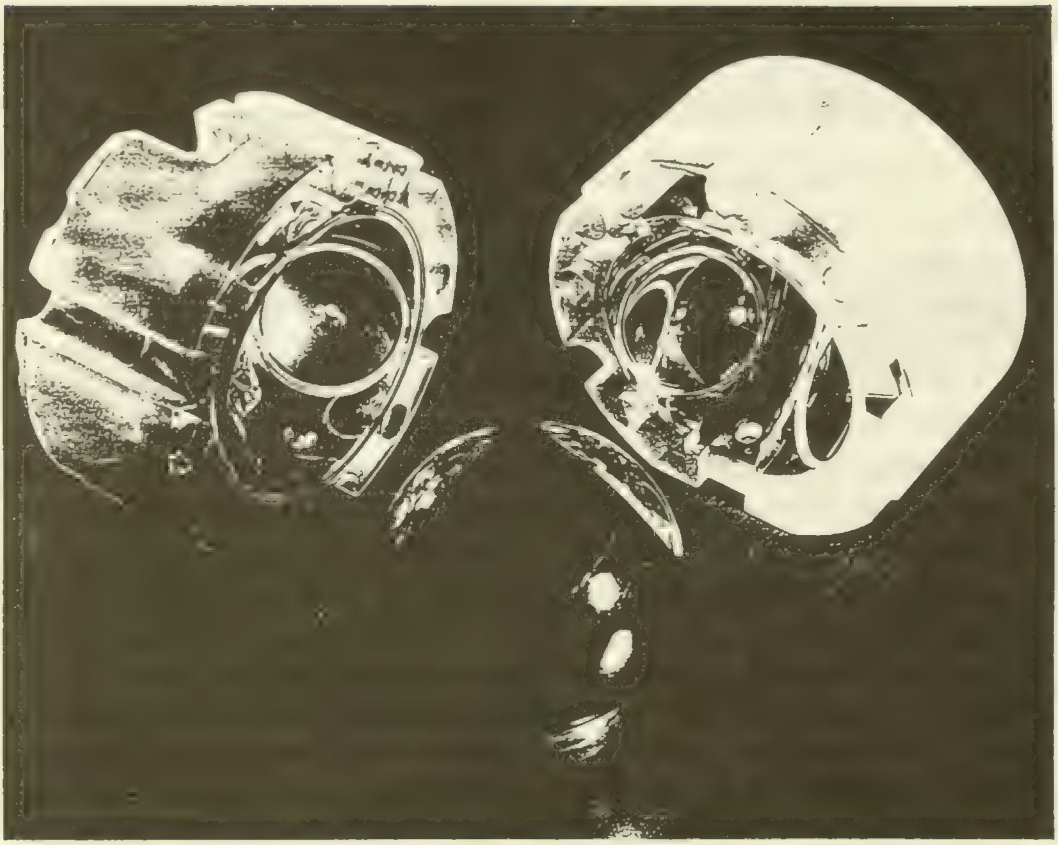
Gravity Probe B has benefited from, and contributed much to, young minds. To date, the program has resulted in 53 completed doctoral dissertations, 20 master's or engineers degrees and 8 undergraduate honors theses. Currently, we have 43 graduate students and 18 undergraduate students in ten departments at Stanford University and 17 students in other institutions. Altogether (including summer jobs) some

250 students have worked on this program since its beginning. We have even been able to involve a small but significant number of high school students in appropriate circumstances.

It may seem surprising that students can find satisfactory projects in a program that has taken many years to develop as Gravity Probe B has. The reason is that we have been able to involve the students deeply in the *invention* of the mission. To give a few examples, students have been key to the inventions of (1) the gyro spin system, (2) the gyro readout system, (3) a new kind of gyroscope suspension system, (4) a method of obtaining the lowest magnetic field ever, (5) the new standard technique of the 'porous plug' for controlling liquid helium in space, (6) gyro rotor measurement technology, (7) development of novel spacecraft thrusters, (8) new methods of orbit adjustment, spacecraft orientation, data reduction, and instrument testing — to name a few.

Both graduates and undergraduates have contributed to these inventions, and many interesting careers have grown from Gravity Probe B. And there have been many unexpected and impressive spinoffs. Thus the low magnetic field technology mentioned earlier has contributed to the development of superconducting computers. The GP-B-invented porous plug has been essential to the success of NASA's IRAS, COBE and the future SIRTF program, as well as the European ISO program. One of the most remarkable spinoffs has been the extension of a spacecraft orientation system devised by a GP-B student using GPS (Global Positioning System) technology to provide a new and extremely promising airplane safe landing system recently demonstrated successfully in 110 landings of a Boeing 737.

These specific inventions and spinoffs are exciting and are to be expected, but in some ways I would prefer to leave you with an emphasis on the human rather than the strictly technical side of the story. William Fairbank, who was one of the three original driving minds behind Gravity Probe B, once remarked to me that the most important lesson a student needs to find is a setting that makes him or her believe that it is possible to make new contributions to science or engineering. That is what leads to a productive career later on, in whatever field one may eventually choose to work. That is the atmosphere we have sought to establish in Gravity Probe B, I think successfully. With your support Mr. Chairman, ladies and gentlemen we will continue it and bring this exciting venture to success.

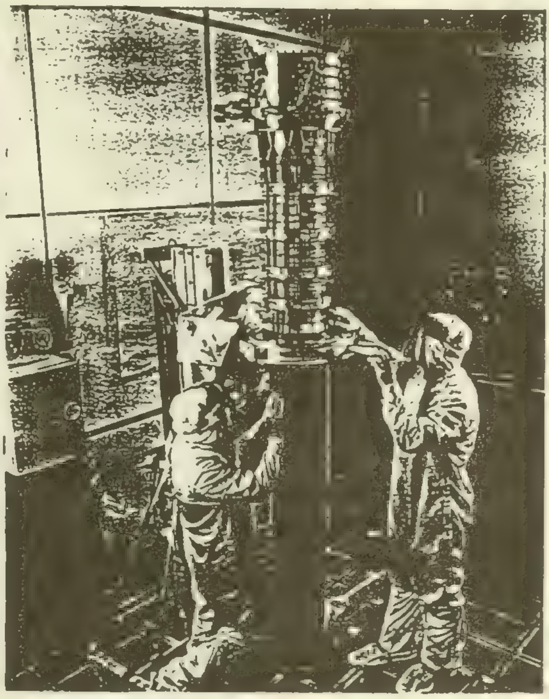


GRAVITY PROBE B FLIGHT GYROSCOPE

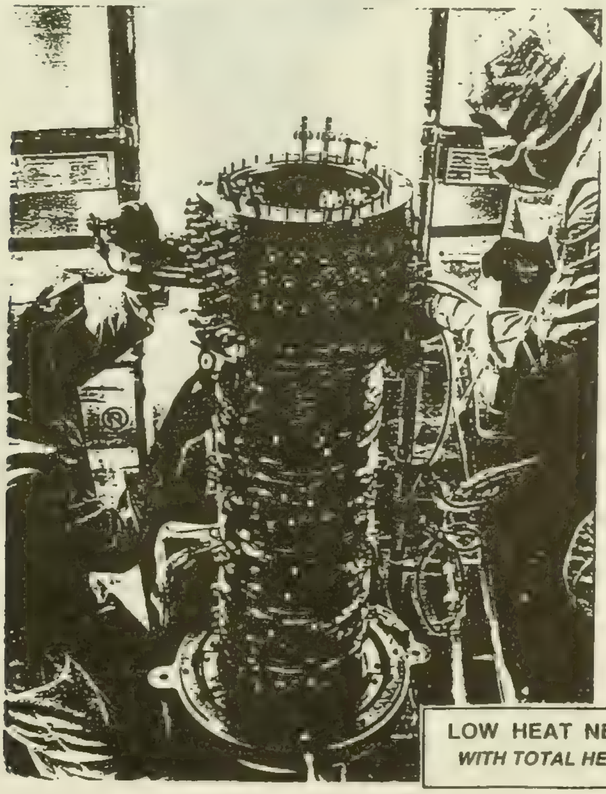
THE GRAVITY PROBE B GYROSCOPE IS A SPHERE OF FUSED SILICA (A SPECIAL KIND OF GLASS) MADE ROUND TO BETTER THAN A MILLIONTH OF AN INCH AND COATED WITH A THIN LAYER OF SUPERCONDUCTING METAL. IT IS SUSPENDED ELECTRICALLY IN THE FUSED SILICA HOUSING SHOWN BY APPLYING VOLTAGES TO THE SAUCER-SHAPED 'ELECTRODES' IN THE HOUSING. GAS THEN FLOWS AT NEARLY THE SPEED OF SOUND THROUGH THE CHANNEL IN THE RIGHT-HAND HOUSING, SPINNING THE GYROSCOPE TO 10,000 REVOLUTIONS PER MINUTE, AFTER WHICH IT IS PUMPED TO AN EXTREMELY HIGH VACUUM. THE DIRECTION OF SPIN IS READ VERY EXACTLY BY MEANS OF A SUPERCONDUCTING DEVICE CONNECTED TO THE METAL LOOP ON THE FLAT FACE OF THE LEFT-HAND HOUSING.

FLIGHT HARDWARE FOR GRAVITY PROBE B

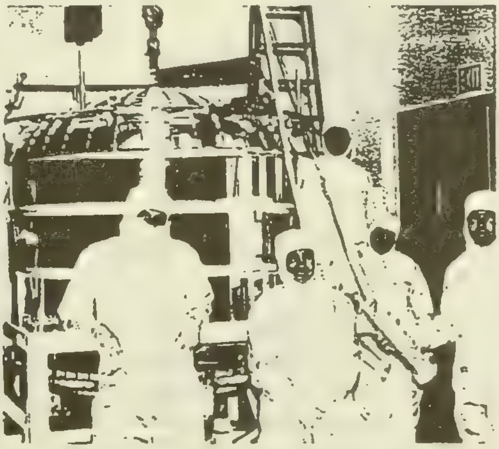
GRADUATE AND UNDERGRADUATE STUDENTS WITH SQUID ELECTRONICS
A MILLION TIMES MORE SENSITIVE THAN A HOME STEREO AMPLIFIER



FLIGHT INSTRUMENT ASSEMBLY
FULLY TESTED AND SHIPPED TO STANFORD IN AUGUST 1994

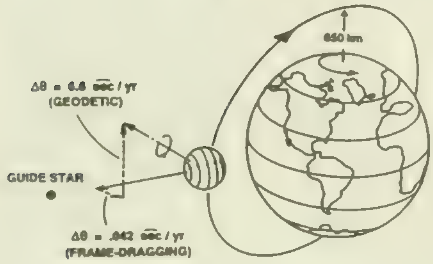


LOW HEAT NECK TUBE – *OVER 400 WIRES AND CABLES WITH TOTAL HEAT LEAK SMALLER THAN 0.1 WATT*



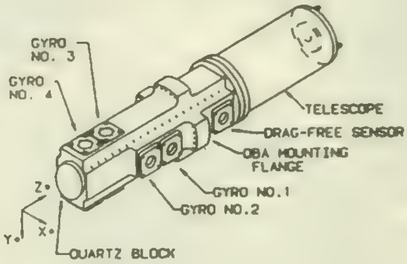
MAIN TANK OF FLIGHT DEWAR – *VACUUM TESTS COMPLETED SUCCESSFULLY IN JANUARY 1995*

THE GRAVITY PROBE B RELATIVITY MISSION


650 km
$\Delta\theta = 6.6\ \widehat{\text{sec}}$ / yr
(GEODETIC)
GUIDE STAR
$\Delta\theta = .042\ \widehat{\text{sec}}$ / yr
(FRAME-DRAGGING)

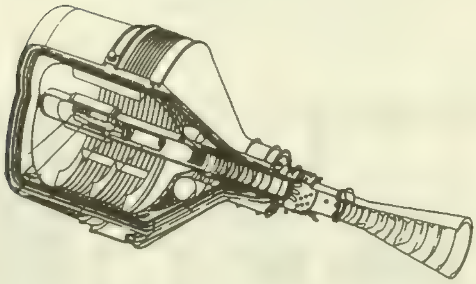
THE TWO GYRO EFFECTS PREDICTED BY SCHIFF

A SPINNING BODY MOVING AROUND THE EARTH MEASURES THE EINSTEIN DISTORTION OF SPACE (GEODETIC EFFECT) AND ALSO THE STRANGE 'DRAGGING' OF SPACE BY THE ROTATION OF THE EARTH.



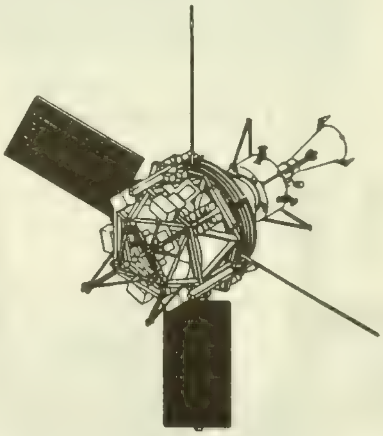
THE GRAVITY PROBE B FLIGHT INSTRUMENT

FOUR GYROSCOPES AND A PRECISE TELESCOPE ARE MOUNTED TOGETHER TO THE GP-B INSTRUMENT. THE EXPERIMENT MEASURES SMALL CHANGES IN THE DIRECTION OF SPIN OF EACH GYROSCOPE WITH RESPECT TO A DISTANT STAR.



THE GRAVITY PROBE B FLIGHT PAYLOAD

THE GP-B INSTRUMENT IS PLACED IN A SHIELDED, EVACUATED CHAMBER INSIDE A 'DEWAR VESSEL' (THERMOS BOTTLE) CONTAINING 500 GALLONS OF LIQUID HELIUM AT VERY LOW TEMPERATURE. THE DEWAR REMAINS COLD FOR 18 MONTHS.



THE GRAVITY PROBE B SPACECRAFT

THE SPACECRAFT POINTS AT THE GUIDE STAR AND ROLLS SLOWLY ABOUT THE LINE OF SIGHT. DATA IS TRANSMITTED TO GROUND ONCE EVERY TWELVE HOURS, THE MISSION LASTS 18 MONTHS.

RELATIVITY MISSION - GRAVITY PROBE B - TOTAL PROGRAM COST

PROGRAM COMMITMENT (COST) AGREEMENT - FORMALLY AGREED UPON BY NASA HQS OSS, NASA MSFC & STANFORD UNIVERSITY ON 1 JULY 1994

INVESTMENT THROUGH FY 1995:

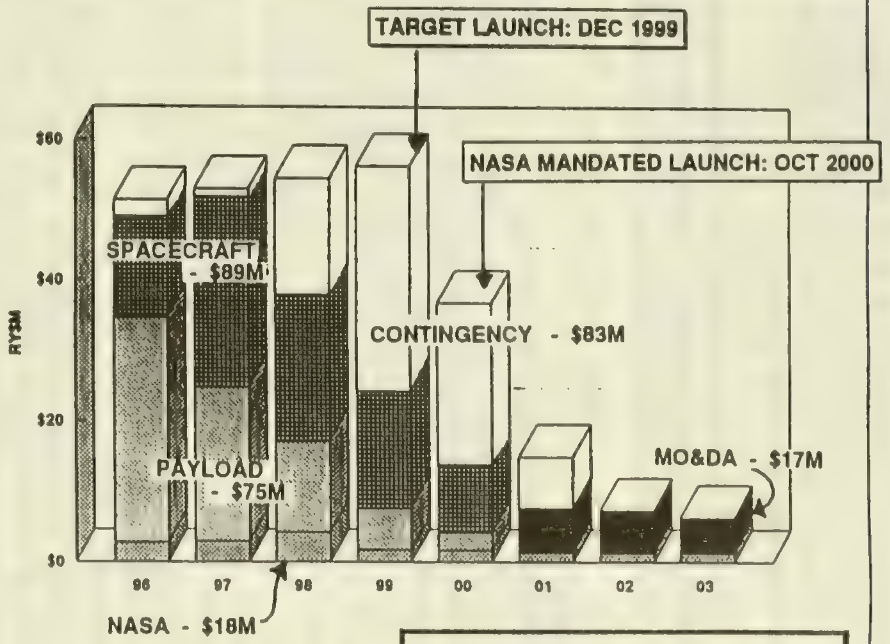
...BASIC RESEARCH FY's 1964 - 1984: $16M
...STORE PROGRAM FY's 1985 - 1995: $220M
=====
$236M

INVESTMENT PAYOFFS:

... PROTOFLIGHT INSTRUMENT & PROBE
... FLIGHT DEWAR IN FABRICATION
... FIRM, LOW RISK COST ESTIMATE

OCT 2000 LAUNCH CONTINGENCIES:

... SCHEDULE SLACK : 21 mos (29%)
... COST CONTINGENCIES:
.... STANFORD HELD: $35M
... NASA MFSC HELD: $48M
====
$83M (42%)



BASELINE COST: *$199M*
CONTINGENCY: *$ 83M*
=====
TOTAL: *$282M*

ALL COSTS IN RY$M

* INCLUDES ALL COSTS EXCEPT LAUNCH VEHICLE

Mr. SENSENBRENNER. Thank you very much, Dr. Everitt. Next up is Dr. Boynton of the University of Arizona at Tucson.

And, I understand that you wish to have one of your graduate students talk for part of your time. That is fine with me as long as he identifies himself for the record.

STATEMENT OF WILLIAM BOYNTON, PROFESSOR OF PLANETARY SCIENCES, CHAIRMAN, SPACE SCIENCE WORKING GROUP, UNIVERSITY OF ARIZONA, TUCSON, ARIZONA.

Mr. BOYNTON. Okay, that will be fine. He is actually an undergrad student.

Mr. SENSENBRENNER. Stand corrected.

Mr. BOYNTON. Thank you, Mr. Chairman, for the chance to talk to the Committee this afternoon about the future of space science.

This past year has actually been really a very fantastic and exciting time for space science. Some of you may have realized—one of the most recent issues of "Time" magazine featured these really stunning photos that have come in from the Hubble Space Telescope, and now people are actually talking about how is it that stars can possibly exist that are older than the universe itself?

Questions such as these having to do with the age, origin and destiny of the cosmos are questions that have really fascinated everyone from school ages on up.

This last summer, you may remember, there were fragments of this comet, Comet Shoemaker-Levy 9, that struck Jupiter, each fragment bringing with it explosive energy of millions of megatons of TNT, and people could see the bruises caused by these impacts from their backyards, using just small telescopes.

The pictures from this event were so striking and so much in demand that when they were put out on the Internet, it nearly brought the information superhighway to its knees. There is really a lot of interest in what is going on here.

There are really a lot of amazing discoveries, and these amazing discoveries will never cease, but one thing that is important is that spacecraft missions do cease, they do end. They are planned to end.

Last summer marked the fiery demise of the Magellan Space Craft as it burned up in the atmosphere of Venus. This is after five years of mapping the planet by peering through the clouds with its radar system.

And as one mission ends, another must begin if we are ever to continue to satisfy the public thirst for knowledge about the nature of our planet and our place in the cosmos.

To persevere, NASA does need new missions. NASA's new approach in this era of dwindling funds, is to launch much cheaper missions, to launch them more often, and to limit them to shorter times.

For example, in the New Discovery program, one of the requirements is that the missions must be launched in less than three years. That compares with the six to ten years of many of the missions in the past.

Some of the discovery missions are being run out of universities, where this accelerated time line fits in nicely with student involvements, and instead of waiting years or decades for New Missions, students can participate in a mission from start to finish.

NASA missions have always inspired the public, and it is particularly important to inspire our young people, who will lead our increasingly technological society into the next century.

NASA can inspire grade school kids to keep pursuing careers—keep pursuing the classes in math and science, so that they can go into these careers and not get discouraged along the way.

Budgetary times are difficult, of course, and space science, despite the promise it holds for the future, is being hit with an eighteen percent cut between now and the year 2000, as I am sure you well appreciate.

And, of course, this cut does not include the extra cut due to inflation. It is actually twice the nine percent cut that NASA is facing in its overall budget.

It really wastes, I think, our nation's valuable scientific resources to have our brightest minds work on a mission designed for flight, and then have it cancelled. This year's budget is no exception. The entire field of space physics has no missions budgeted through the year 2000, even though the timed mission, the first of the solar terrestrial probes, was authorized in last year's budget to begin in Fiscal Year '96.

And like the Discovery Series, the solar terrestrial probes use small space craft to conduct focused studies, and in this case, our most important star, the sun, and the most important planet, earth.

Suggestions that there may be no new starts this year if implemented would surely kill all the faith in the, "new way of doing business." The smaller, cheaper, faster approach to missions will be viable only if they are launched on the regular basis in which they are planned.

And the excitement that is coming with this new way of doing business has captured the interest of many of the students at my university, the University of Arizona, at Tucson.

And one of these students is here with me. He is Chris Lewicki, a junior who is working with me on the Near Earth Asteroid Rendezvous Mission. This is the first of one of the Discovery series, and with your permission, Mr. Chairman, I would like to ask Chris to say a few words about the student involvement that we had planned in our proposal for the Discovery Mission follow-on.

[The prepared statement of William Boynton follows.]

SPACE SCIENCE WORKING GROUP

Testimony on

NASA's Space Science Program

Presented by

Dr. William Boynton
Professor of Planetary Sciences
University of Arizona

on behalf of the
Space Science Working Group
of the Association of American Universities

for the
U. S. House of Representatives
Committee on Science
Subcommittee on Space

March 16, 1995

c/o Association of American Universities • Suite 730 • One Dupont Circle
Washington, DC 20036 • 202/466-5030 • FAX 202/296-4438

Thank you for the opportunity to testify before the House Subcommittee on Space. I am Bill Boynton and speak today on behalf of the Space Science Working Group (SSWG) of the Association of American Universities. The SSWG represents several hundred space scientists at approximately fifty universities nationwide.

Despite cuts in its budget, NASA can still provide a program that excites the public. A recent issue of *Time* magazine featured spectacular images from the Hubble Space Telescope and described some of the truly fundamental questions raised about the origin, age, and destiny of the universe. Last summer, we were all captivated by images of fragments of Comet Shoemaker-Levy 9 impacting into Jupiter. As the public sought these pictures on the Internet, the information superhighway was nearly brought to its knees.

NASA excites the public, especially school children. Space missions are a unique way to excite future citizens who will play leading roles in our society as our nation enters the increasingly technological age of the 21st century. We must excite kids about math and science while they are in grade school. NASA can do this.

In order to continue with this exciting program, it is essential to approve the missions that are scheduled for "new" starts. It may at first seem remarkable that new missions would even be considered in times of decreasing budgets, but they are essential now, considering the way NASA has changed to cope with shrinking budgets.

NASA, and especially the Office of Space Science, is very different from other parts of the government in the way it must do business. New starts for NASA are not like those for other government programs; NASA's missions begin and end. While one mission is being planned for a possible new start, another is traversing vast interplanetary distances, another is in orbit around a planet, and a still earlier mission has ended and its data are being analyzed. Without continuing new starts, the current missions will soon meet their goals, and there will be no space science exploration.

Both NASA's budgetary plans and its Space Science Program have taken big cuts in recent years. Figure 1 shows that the FY91 through FY93 budgets for NASA had planned growth that exceeded the rate of inflation, but actual budgets never lived up to expectations. Beginning with the FY94 budget, the budget planning became less optimistic, but even these projections have not been met. The cuts now projected for the future are not just in the form of "cuts in the rate of growth;" they reduce real spending. The current plan shows a real decrease in spending in FY2000 of about one-third of the FY91 level. In current dollars, the planned cuts in Space Science are 18%, twice the 9% cut in NASA as a whole.

These planned budget cuts have been especially severe in the Space Physics Division, where there are no missions planned from now through the year 2000. This delays for the foreseeable future the Solar Terrestrial Probes, which focus on the most important star, our sun, and its linkages with the most important planet, Earth. Like the Discovery series, the Solar Terrestrial Probes employ small spacecraft and highly focused studies of solar variability and its influences. Last year's House and Senate authorization bills called for a new start in the TIMED mission–the first of the Probes–as a FY96 initiative. TIMED will investigate the connection between highly variable short-wavelength solar radiation and the response these variations cause in the outermost layers of the Earth's atmosphere.

Another potential problem with the budget is that no allowance has been made for the Gravity Probe-B mission (GPB). This mission is designed to carry out a fundamental test of General Relativity. After a long NASA-funded development program, GPB is in the flight-hardware-development phase in anticipation of a 1999 launch. The GPB mission is currently under review by a committee of the National Academy of Sciences. Its report is expected by early this summer. If that study concludes that GPB should continue to be funded, it will cause additional pressure on the remainder of NASA's budget.

NASA's Emphasis on Smaller Missions

NASA is trying a new approach of flying a continuing series of imaginative, low-cost missions that address focused, but important, scientific goals. These missions are easier to plan and are quicker to develop because they are far less complex. Instead of launching a three-billion-dollar mission once every ten years, NASA can launch a 200-million-dollar mission every year and save much money in the process. They provide many more opportunities to be innovative, to develop new technology, to involve students, and to do good science. We benefit from smaller missions only if we fly enough of them and plan them efficiently. With frequent launches, the technology and knowledge learned in earlier missions can be improved upon with each new mission.

These smaller missions provide many more opportunities for wide dissemination of knowledge to the citizens paying for them. In addition, by running them from universities, which is unprecedented in the Solar System Exploration Division, there are far more opportunities for students to be involved.

Specific examples of this new approach in the proposed budget are the emphasis within the Planetary Division on a continuing series of Discovery missions and the continuation of the Mars Surveyor series in place of the multi-billion dollar efforts of the past. The New Millennium program would infuse new technologies into spacecraft to reduce their cost in the future and, within Astrophysics, the descoping of SIRTF would permit a modest mission while retaining its ability to do Great-Observatory class science.

The Discovery Program

An example of the exciting things NASA is planning for the future is the "Opportunity" part of the Discovery program of small missions. Each of the recent proposers to this program, of which there were 28, was required to discuss how their mission would enhance the opportunity for the citizens to benefit from their project. They were specifically asked to discuss the use of new technology, its infusion into the non-space industry, the opportunity for participation by small and small-disadvantaged businesses, the enhancement of public awareness of the benefits of the mission, and the ways in which the mission would benefit the nation's educational program.

So that the Congress can appreciate what is involved, I would like to discuss a personal example of a program that may be typical of what could be expected in the educational area of the Discovery missions. The selected missions were just announced, so I do not have much first-hand knowledge of their educational plans, but I can describe the plan that was incorporated in my own proposal to the Discovery Program.

We planned on working closely with the Arizona chapter of the Students for the Exploration and Development of Space (SEDS), a national organization of mostly undergraduate students. This group would help in operation of the spacecraft, a function that was going to take place right on campus, rather than at a NASA center. Late in the mission, the entire mission operations function would be turned over to SEDS to manage entirely as their own for a full month. At the end of the mission, the students would continue to operate the mission using internal, non-NASA funds until the spacecraft ran out of fuel.

The Discovery program considers more than just university-level education to be important, however. We planned to reach out to the middle- and high-school level students through the University of Arizona's Image Processing for Teaching Program. This is a program run by the University that reaches students through a program of week-long workshops that instructs teachers on how to use image processing in their curriculum back at their home schools. The program follows up the workshop over the next year to make sure that the material is continuing to be used effectively. (We planned a special emphasis on reaching the Native American tribes in Arizona and New Mexico.) The advantages of using teachers to reach the students is that we are leveraging our effort with the infrastructure that already exists in the schools throughout the nation. In this way we expected to reach over a million students, far more than we could ever hope to reach by direct contact.

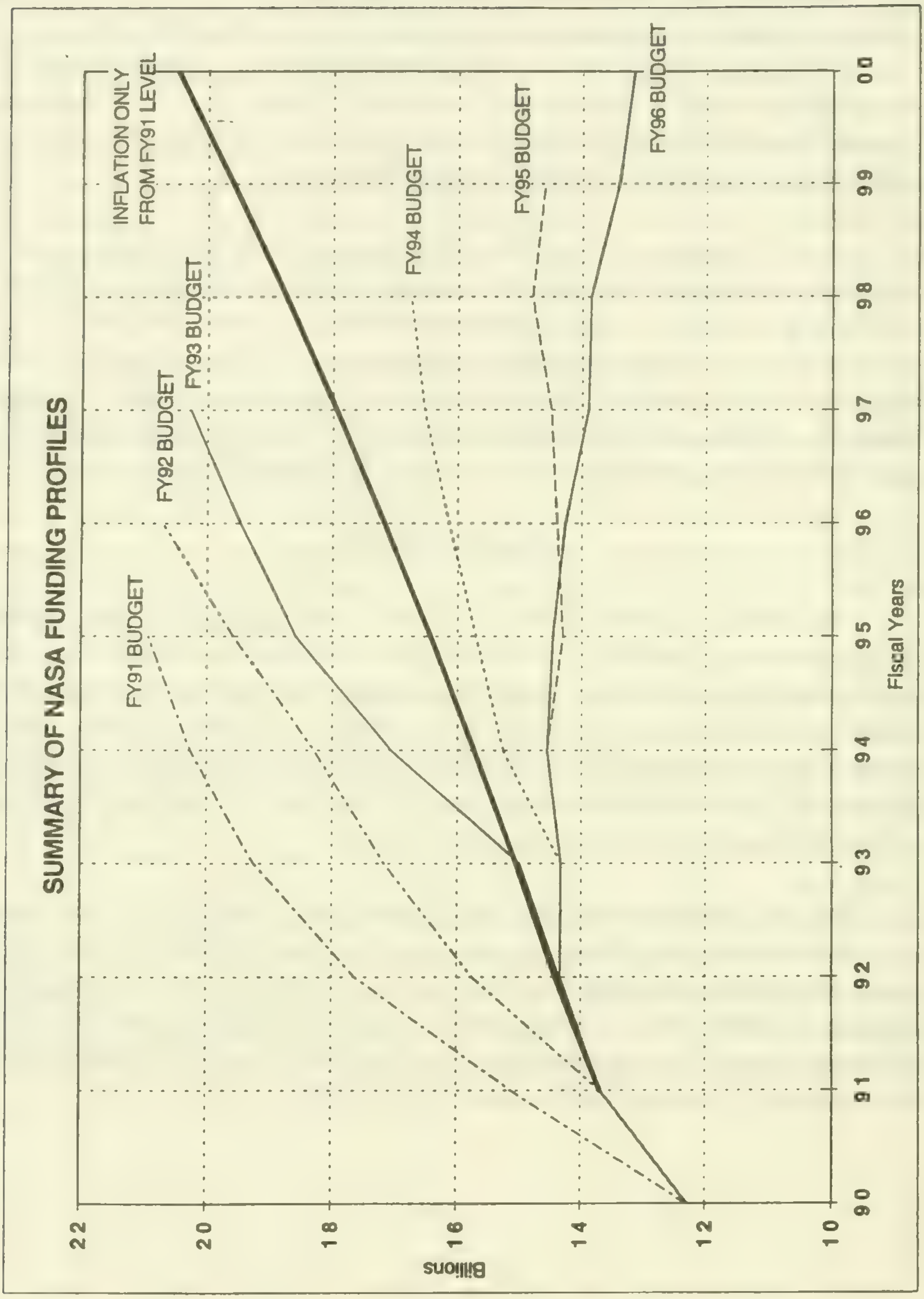
Although these are only examples of my approach to making NASA space science relevant to the students of the country, it shows what can be expected with these small, university-run missions. The Discovery Program is clearly committed to being relevant to other parts of our society, and it seems clear from the missions opportunity announcements that I have seen since Discovery, that NASA intends that other missions have a strong educational component as well.

NASA is trying to cope with the desires of both the Congress and the Administration to reduce the costs of its programs yet maintain the quality of its product. By changing its emphasis to these small and moderate class missions, the Office of Space Science at NASA has adjusted well to the environment in which it must work. When the public begins to see the results of these new missions that are now only partially complete, and they see the extent to which school kids are getting excited, they will have a much better appreciation of the value they are getting for their money.

Recommendations

1. The small to moderate missions for which new-start approval has been requested should receive high priority. It is important to fund the definition of SIRTF, which has been extensively descoped to fit within the budget while preserving its high-priority science capabilities, and to fund the start of SOFIA, which has an urgent need to preserve a critical international collaboration. It is especially important to approve Mars Surveyor and Discovery as continuing programs. These two lines were approved last year only as individual missions, not as continuing programs.

2. We are concerned about the lack of space-physics missions in the new budget, since solar-terrestrial studies are of great interest to space science and are the only means for obtaining new insights into our sun and its impact on Earth. The importance and benefits of the Solar Terrestrial Probe series of small missions is very high, and it should be initiated. Even a partial restoration of the 18% decline in OSS funding to the level expected for the rest of NASA would allow it to begin.


SUMMARY OF NASA FUNDING PROFILES
INFLATION ONLY FROM FY91 LEVEL
FY91 BUDGET
FY92 BUDGET
FY93 BUDGET
FY94 BUDGET
FY95 BUDGET
FY96 BUDGET
Billions
22
20
18
16
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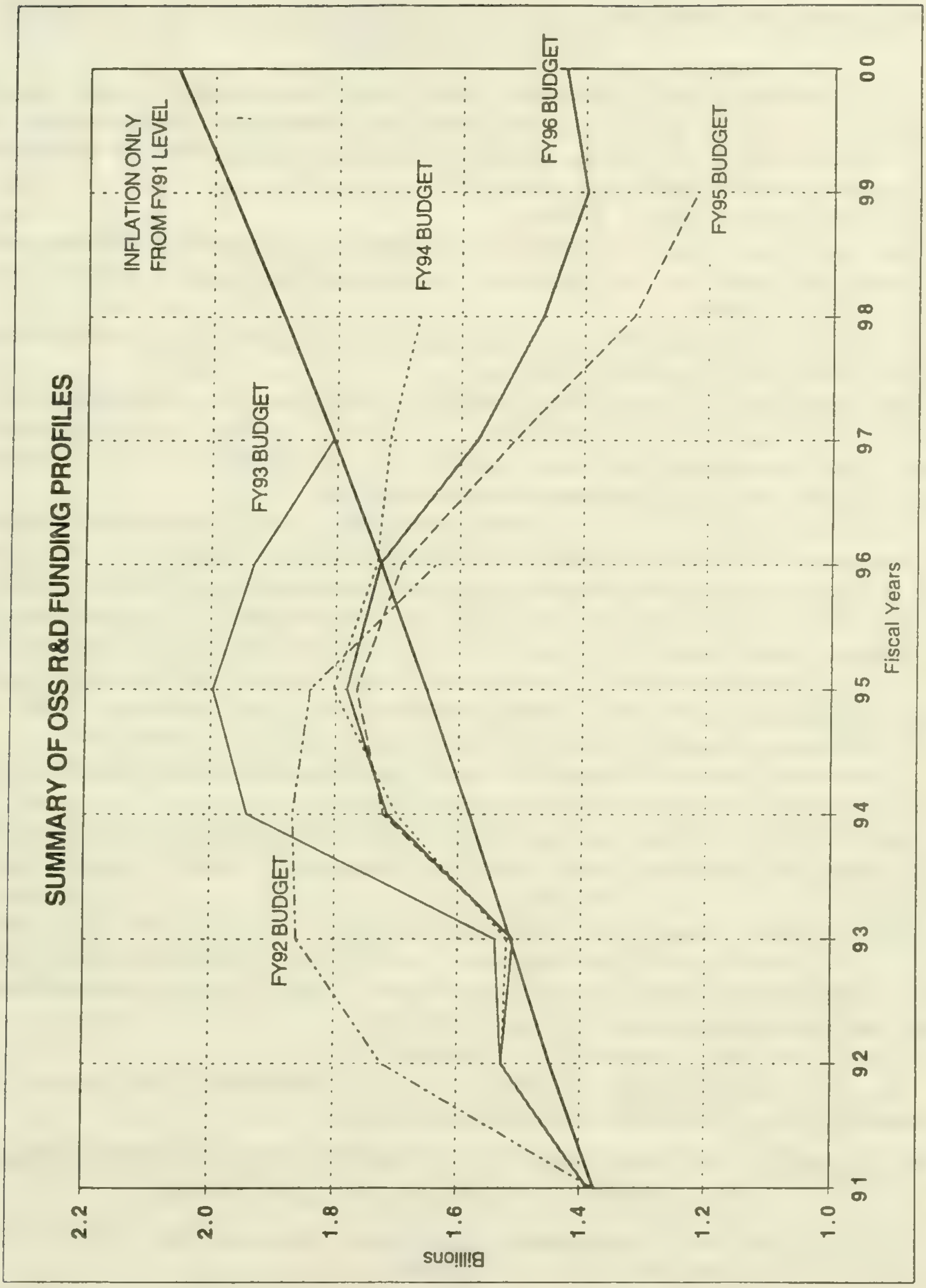


SUMMARY OF OSS R&D FUNDING PROFILES

Mr. SENSENBRENNER. Mr. Lewicki is recognized.

STATEMENT OF CHRIS LEWICKI, UNIVERSITY OF ARIZONA JUNIOR STUDENT.

Mr. LEWICKI. Good afternoon, Mr. Chair. As he said, I am Chris Lewicki, an undergraduate student in Aerospace Engineering at the University of Arizona, and Dr. Boynton asked me to speak on opportunities available for students.

Mr. SENSENBRENNER. Please.

Mr. LEWICKI. One of the goals outlined on Discovery Mission opportunities, was that of exciting and involving this country's students and citizens.

Dr. Boynton's Discovery proposals had two unique opportunities, which I will briefly outline here.

The proposal Gravity Sub-Satellite was based on a design for an earth orbiting amateur satellite, SEDSAT, which was designed, built and is soon to be flown aboard the space shuttle by students at the University of Alabama at Huntsville.

Another approach for involving students allows the direct control of the space craft by the students themselves. During the last quarter of the mission, we would go through a month of driver's ed, so to speak, to become familiar with the operation of the spacecraft.

When the mission had reached the end of its NASA-funded life time, Dr. Boynton would, in a sense, turn the keys to the spacecraft over to the students, who would operate their own mission until internal funds or space craft fuel ran out, whichever came first.

These are just a few specific examples of many opportunities that NASA space science can create in students.

Mr. BOYNTON. Thank you, Chris. I tell you, these are very exciting times for space science, and let us plan for vital space science program for the 21st Century.

The budgets must be constrained. That is clearly reality, but I say let's handle the funding that is allocated for these endeavors with intelligence and commitment, and I think our students and our nation's future really depends on it.

Thank you very much, Mr. Chairman.

Mr. SENSENBRENNER. Thank you, Dr. Boynton. Next up is Dr. Lester of the University of Texas at Austin.

STATEMENT OF DAN LESTER, DEPARTMENT OF ASTRONOMY, UNIVERSITY OF TEXAS, AUSTIN, TEXAS.

Mr. LESTER. Mr. Chairman, members of the subcommittee, thank you for the opportunity to testify today.

I am an active research astronomer at the University of Texas, and I am here to tell you about efforts to explore what we see as a new frontier of space infrared astronomy.

This is where the SOFIA and SIRTF programs are going to break fundamentally new ground.

Most of the light in the universe, and the light in this room, in fact, is infrared light. But this light is largely blocked by our atmosphere so, as seen from the ground, the sky is perpetually cloudy. The suite of great observatories that have gone up—the Hubble, Compton, and very soon AXA7—extend our view of the universe from the visible all the way to the gamma rays, and thus they probe a whole range of different phenomena. They are making profound and exciting discoveries. The flexibility and accessibility of SOFIA, the unparalled sensitivity of SIRTF, make these two millions powerful and completely complementary elements of a careful plan to explore the rest of the spectrum, the infrared frontier.

I am going to confine my testimony mainly to SOFIA, the Stratospheric Observatory for Infrared Astronomy, because NASA is requesting substantial funds in FY '96 to purchase the airplane and start to modify it.

Let me say at the outset that the U. S. astronomy community has very carefully set priorities. Our request for SIRTF and SOFIA is the end result of that process.

We have made some very hard choices. We have cut our existing programs to the bone. We have shut down programs in order to ask for programs within what we completely realize to be a rapidly declining budget.

We are even going to shut down the still productive Kuiper airborne observatory, a much smaller airborne observatory, to offset SOFIA's development costs.

Now, new opportunities are what drive creativity. They spur new technology. They define our scientific vitality. Exploration is based on opportunities, and SOFIA is all about opportunities.

SOFIA is a big telescope in a Boeing 747. You have a picture in the package that you have.

It is going to fly in the stratosphere where the infrared sky is clear. It will be hundreds of times more capable than the Kuiper Observatory, which it will replace.

From the stratosphere, SOFIA is going to see stars and planetary systems being formed. It will probe the mysteries of the center of our galaxy. It will help us understand the huge clouds from which stars and solar systems are being born.

But SOFIA is a very special way of doing space science. I want to impress that on you.

First of all, it isn't just one mission. Every year SOFIA will do a hundred and sixty research flights, and you can look at this way. That's a hundred and sixty "launches" per year. That is a hundred and sixty opportunities per year to do something different.

Each year probably fifteen different science instruments are going to view the sky from the stratosphere with SOFIA. Several of these will be brand new every year. These instruments are accessible. Not only can they be changed in between flights—the airplane goes up, it comes down, you change them—but scientists and students actually get to fly along with them. This is real hands-on space astronomy.

The equipment gets modified, upgraded and fixed in real time.

Accessibility means inexpensive instruments that push the limits of technology. They don't have to be space qualified. They don't have to be super-reliable. They can come straight out of the lab and do great science.

SOFIA instruments will, as a result, always be state of the art, which is changing very fast in the infrared.

Accessibility means training. The next generation of space astronomers is going to cut their teeth on SOFIA. They are going to build instruments as students, and they will see them all the way from inception through discovery. That is a good way to make technological and scientific leaders.

Accessibility means visibility. SOFIA is going to be able to deploy all around the country in the course of its research flights. It is going to be a flagship for U. S. space technology, and bring space science down to earth.

I want to tell you about an exciting program that we are doing on the small Kuiper observatory. On every research flight we take two K-12 teachers with us.

They experience the excitement of research and discovery from a night in the stratosphere. They communicate that excitement back to their students and, probably most importantly, they forge contacts with the research community. That has been one of the real gains for me as an astronomer who has participated in this.

This is teacher in space in the stratosphere. We are going to do this outreach in a greatly expanded way on SOFIA.

We have responded to the realities of a declining budget. Germany has agreed to buy into this project at twenty percent, although the duration of this commitment may be limited to FY '96.

The cost of used 747s is at an all time low. All the budget projections say that it is going to go back up. Finally we are going to terminate the productive Kuiper observatory to make a cost offset on development.

The plan for SOFIA is backed by a twenty year investment in airborne astronomy, and it is time to take the next step.

Thank you.

[The prepared statement of Dan Lester follows.]

Statement for the Hearing

"NASA: The Outside Opinion"

March 16, 1995

Presented by

Dr. Dan Lester
Research Scientist
Department of Astronomy and McDonald Observatory
University of Texas at Austin

to the Subcommittee on Space and Aeronautics
of the Committee on Science

United States House of Representatives

Thank you for the opportunity to testify before the Subcommittee today.

I am a practicing astronomer working primarily in infrared astrophysics, and have been deeply involved in the effort to develop the Stratospheric Observatory for Infrared Astronomy (SOFIA), as well as advising NASA on their plans for initiatives that will explore the cosmos in the infrared. I would like to impress upon you today, from the perspective of an active scientist in the community, the opportunities that infrared missions provide, and the importance, uniqueness, and complementarity of the SOFIA and the Space Infrared Telescope Facility (SIRTF) endeavors, which are highlights of the FY96 NASA budget request. Since NASA proposes to initiate its development by means of an augmentation to the existing airborne astronomy line, my testimony will emphasize SOFIA.

I would like to underscore not only the discovery potential that a carefully planned infrared astronomy program will provide us with, but the national needs for science education and continual technology development in which SOFIA, in particular, will break new ground. I am also compelled to inform you that the opportunity to achieve SOFIA is perishable. *We have invested a lot in the development of airborne astronomy, and SOFIA in particular.*

Let me emphasize to you at the outset that the astronomical community has carefully set priorities, and that our commitment to these two initiatives is the result of that process. We have made very hard choices and deep cuts in order to promote these missions in a way that is fiscally responsible.

Astronomy, New Initiatives, and the Spirit of Exploration

In the last thirty years, we have participated in an explosion of new understanding about the cosmos in which we live. From mountaintop telescopes to observatories in space, our perspective on the Universe has flourished. Future generations will look back on these decades as having produced some of the most powerful and productive tools for scientific exploration that we ever built. With these tools, our understanding of the cosmos has changed profoundly.

It is a matter of great pride for us as a nation that we have been able to lead the world in so adventurously exercising our curiosity about the Universe in which we live.

The heritage that we leave for future generations is not just knowledge of the scale of the Universe, or evidence for black holes in the hearts of galaxies, but the spirit of exploration of the world around us. For it is this spirit of exploration, and the curiosity that drives it, that is one of our most profound national needs. A nation that stops exploring is a nation that cannot produce the scientists and technologists that we so desperately need to be competitive in the global economy, and to improve the human condition. Federally funded scientific research is a contract with the U.S. taxpayer not only to create new products, but to satisfy the national curiosity about the world in which we live. It is a fundamental element in the federal investment portfolio that insures our leadership in the world.

The cultivation of curiosity about our physical world is a need for which astronomy has special potential. It is increasingly evident that scientific literacy in our nation is a problem as much for our elementary schools as for our graduate schools. K-12 is where science, which is nothing less than a systematic approach for exercising curiosity about the world, is first taught. This is not only where future scientists are inspired, but where future taxpayers develop their respect for science as a tool and for scientists as explorers who are working for them.

The appeal of things astronomical to young children as well as adults is both striking and manifest. Astronomy is an accessible and easily appreciated metaphor for science as exploration. Looking out into space represents exploration, to the youngest minds, better than bubbling beakers in basement labs. As their scientific sophistication increases, our youth can use the excitement that astronomy gives to them as a foundation for enthusiasm about molecular biology or particle physics.

Central to exploration as the embodiment of the scientific endeavor is the importance of new opportunities. New data nourishes the scientific process. Unlike a factory that stamps out parts, the scientific process requires continual retooling to be productive. The vitality of scientific research is inextricably linked to new opportunities. The most productive of scientific endeavors, especially those that feed heavily on and drive technological advances, are ones that embrace an iterative strategy. In this strategy, instruments are built to answer questions, but the answers to those questions highlight new questions that require new kinds of measurements and new instruments to make them.

Scientific discovery proceeds in tandem with new opportunities to do it.

In their 1991 Report "The Decade of Discovery in Astronomy and Astrophysics" a National Academy of Sciences committee prioritized the needs for a vital program of U.S. astronomy. The highest priority identified by the "Decade Committee" was the need to achieve a programmatic balance between large, expensive, and infrequent missions, with more frequent smaller missions, and the need for regular opportunities to do space astronomy. The availability of frequent access spurs not only scientific discovery, but education, training, and technology development.

Seeing the Universe in New Ways

These last few decades have been marked by challenging space astronomy missions that have vastly expanded our perceptual horizons. The Hubble Space Telescope (HST) that has, since launch, been very productive, is now the extraordinarily powerful tool that was originally planned. Reaching deep into the history of our Universe, Hubble has now revealed distant galaxies which, from their fragmented and torn appearance, suggest that collisions and close encounters were commonplace among galaxies in the early Universe. At much higher energies, the Compton Gamma Ray Observatory (CGRO) is on the trail of one of the greatest mysteries in astrophysics — the gamma ray bursters. We have no idea where or how they originate but just that, once a day or so, a brief flash lasting only a few seconds outshines everything else in the sky. The Advanced X-Ray Astrophysics Facility (AXAF) is on schedule, with completed mirrors that exceed their specification, with tolerances that are on an atomic scale. AXAF is demonstrating that NASA continues to deliver on technically challenging promises by driving the ingenuity of American industry.

The goal of NASA astrophysics has been to apply unique aerospace capabilities to investigate astronomical problems that cannot be studied from the ground. The protective envelope of atmosphere that surrounds us, which shields us from powerful high energy radiation from space and blocks the infrared radiation, controlling our climate, prevents us from seeing the cosmos in all but narrow windows in the electromagnetic spectrum. With Hubble, Compton, and soon AXAF, we are provided with an unobscured picture of the Universe, from gamma rays, to X-rays, through the ultraviolet and the visible, to the near-visible part of the infrared.

Nevertheless, over two orders of the electromagnetic spectrum in the infrared remain largely unexplored. This part of the electromagnetic spectrum has been widely recognized in the astronomical community as a last frontier, the exploration of which will be enormously revealing. The technological capabilities for doing so efficiently are only now coming available. The Stratospheric Observatory for Infrared Astronomy (SOFIA), for which NASA proposes to initiate development in FY96, and the Space Infrared Telescope Facility (SIRTF), for which substantial predevelopment funds have been requested in this same budget in anticipation of a near-term development start are (along with the Gemini telescopes of the NSF) *critical and entirely complementary elements of a carefully designed plan to explore this new frontier.*

Recognizing in SOFIA and SIRTF their enormous potential for discovery, *the Decade Committee of the National Academy of Sciences ranked these two missions as top priorities among all new space astronomy missions for the 1990s.*

The Infrared Frontier

Nature reveals its secrets at different wavelengths. The most energetic phenomena — cataclysmic eruptions from the centers of galaxies, stars, and the interstellar matter caught in the maelstrom around black holes — shine most brightly in X-rays and gamma rays. Stars themselves, whether alone or in vast galaxies throughout the known Universe, emit most of their light in the ultraviolet and visible. These parts of the electromagnetic spectrum are being opened wide by HST, CGRO, and soon by AXAF.

But space is mostly cold. The majority of the material in space — planets, comets, dust, and gas — is far from sources of heat, and therefore perhaps only a few tens to a hundred degrees above absolute zero. As a result, these objects emit light, and reveal themselves to us, in the infrared as "heat" radiation. In fact, about half of the light in the Universe, and most of the light in this room, is infrared light.

The scientific community has identified several key research areas for which infrared studies provide fundamental insights, and have designed SOFIA and SIRTF specifically with these in mind. Missions like SOFIA and SIRTF, with performance gains that are orders of magnitude over their predecessors, will yield monumental discoveries. Here are some of the problems that they will address.

- *The birth and death of stars*

The origin of stars, and their fate, remain central problems to modern astronomy. We know that stars are born, usually in clusters, within dense clouds of gas and dust. As they die, they again shroud themselves in thick screens of gas and dust. These clouds are opaque to visual light, but the embedded objects emit strongly at infrared wavelengths, to which the clouds are largely transparent.

- *The origin of planetary systems*

We all wonder whether there are other planets, perhaps some like Earth, in orbit around other stars. We do not yet have the technology to observe the feeble light from planets, but observations in the infrared will allow us to directly observe planetary material in the process of formation, as well as to determine the chemical composition of these planetary systems.

- *The clouds between the stars*

Space is not empty. Between the stars lie vast cool clouds of gas and dust, the raw material out of which new generations of stars and planetary systems will be produced. This material shines almost entirely in infrared light, and this light carries information about composition, temperature, density, and whether or not it is actively forming stars.

- *The centers of galaxies*

For decades, astronomers have attempted to understand more fully the enormous sources of energy that are found at the centers of many galaxies, including our own Milky Way. These powerful sources, millions of times brighter than our sun, are buried within thick clouds of obscuring dust, which infrared light can penetrate.

- *The distant cosmos*

One of the great discoveries of this "Century of Discovery" was that the Universe is expanding in all directions, with galaxies rushing away from one another as a consequence of the Big Bang. This rapid expansion shifts the light from distant galaxies into the infrared.

SOFIA - Excellence in Basic Science, Technology and Education

SOFIA will be a powerful facility with unique science capabilities that will help us study the cosmos. This 2.5-m diameter telescope, deployed in a Boeing 747, will build on the rich heritage of the now twenty year old Kuiper Airborne Observatory, which SOFIA will replace. The flexibility of SOFIA will guarantee its long lifetime as an effective facility.

SOFIA is not just a single mission, but a routinely accessible observatory that will allow new space infrared instruments, incorporating technology that defines the state-of-the-art, to be built, proven, and optimized. During its twenty year design lifetime, more than a hundred individual instruments will be deployed on SOFIA, addressing a wide range of astronomical questions.

... Space Infrared Astronomy from the Stratosphere is Cost Effective

The main absorber of infrared light in the earth's atmosphere is water vapor. From the ground, even at mountaintop observatories, the sky is perpetually cloudy throughout nearly all of the infrared. At stratospheric altitudes, however, most of the water vapor is below, and the sky in the infrared is almost completely clear. The vacuum of space allows extraordinarily high sensitivity by cryogenic cooling (see SIRTF below) and there are important classes of astronomical problems that require this sensitivity. For observations in which atmospheric transparency is the only issue, however, observations from an airborne platform are much less expensive than those same observations would be from space. Furthermore, airborne astronomy can put a telescope in exactly the right place, at exactly the right time, to observe special phenomena such as occultations and eclipses.

... SOFIA Represents a Huge Leap in Astronomical Capability

The capabilities of SOFIA far exceed that of the Kuiper Airborne Observatory, which has been in regular and productive use for more than two decades. SOFIA will see stars more than ten times fainter, with ten times greater clarity, and with more than twice the number of flight opportunities. While SOFIA instruments will capitalize on new sensor technologies to provide information at hundreds of times the rate of Kuiper instruments, the facility itself is intrinsically hundreds of times more capable than Kuiper. Through careful planning, and technological innovations, *SOFIA will provide infrared astronomers with this enormous leap in capability at the same cost-per-flight as Kuiper.*

... SOFIA Spurs New Technology and Creativity

SOFIA is a powerful answer to the call for more frequent space astronomy opportunities. 160 research flight per year are planned. While the science instruments on SOFIA are largely accessible in-flight, the opportunity between each 7.5-hour flight to debug, repair, and modify science instruments is a strong inducement to try new things, and to best excercise technological creativity. One can consider each SOFIA flight as a separate opportunity. *In the course of its twenty year lifetime, SOFIA will support more than three thousand such "launches".*

The accessibility of SOFIA instrumentation — the opportunity to get hands-on (with screwdrivers, voltmeters, etc.) an experiment *in situ* — strongly drives instrumentation technology development. Unlike space instruments, for which the relative inaccessibility (when you light the fuse, it's gone) makes reliability a prime design constraint that selects strongly against the newest technology, SOFIA instruments will not require any kind of space qualification. The tolerance for failure that is a hallmark of airborne astronomy encourages entrepreneurial, fast-track, and economical instrument development. While sophisticated space qualified instruments can take a decade to come to fruition, and be very expensive, airborne astronomy instruments can be developed quickly and cheaply, proceeding from the "idea-stage" to the "discovery-stage" in one or two years. For these reasons, *SOFIA will, throughout its entire lifetime, be equipped with instruments that define and even drive the state-of-the-art.*

The Kuiper Observatory has hosted generations of instruments in which sensor technology progressed straight from the lab into the stratosphere, producing valuable technical feedback to the manufacturers from real-world use, as well as science discovery. A recent example of this technology fast-track was the discovery of hot water vapor released above the impact site of Shoemaker-Levy on Jupiter. This was key evidence showing the cometary nature of the impactor. The enabling technology for this discovery was a powerful, but relatively immature infrared detector array that was only a year or two out of the laboratory.

The robustness of airborne astronomy contributes strongly to the expectation of success in development. While the design for SOFIA owes its heritage to the successful Kuiper Observatory, the regular access for servicing assures a facility that meets its performance goals. We know how to do SOFIA, and we have its accessibility as insurance.

... The Educational Missions of SOFIA

The accessibility, mobility, and long lifetime of SOFIA make this facility superbly suited to educational opportunities at all levels. These opportunities have been proven on the Kuiper Observatory.

The accessibility of SOFIA — climb in and go — makes it a facility-of-choice for undergraduate and graduate space astronomy and technology students. Airborne astronomy allows a follow-your-nose approach to space science, in which instruments can be quickly modified to react to new observational opportunities. The short lead time required to develop an airborne instrument has allowed students to take leading roles in instrument production, and see astronomical instrument development all the way from inception through to discovery. This is how scientific leaders are made.

The hands-on modus operandi of airborne astronomy challenges students with making real-time, and quick decisions about a science program. It is just this kind of hands-on, real-time ability that is the foundation of the Space Station science mission. In the twenty years of Kuiper Observatory operation, over fifty students, now in academia, industry, and government labs, used it as a principal tool for their Ph.D. research. The space infrared community of today is largely composed of astronomers who cut their teeth on Kuiper. SOFIA will thus develop America's space infrared community for the next century. *SOFIA is an investment in the scientific future of our nation.*

With the relatively modest cost and scope of SOFIA instruments, many colleges and universities across our country will be able to participate in the excitement of NASA's space astronomy program. Their participation would otherwise be discouraged by lack of expertise in designing and fabricating exotic space-qualified hardware. As documented by authorship of more than eight hundred Kuiper Observatory publications in professional journals, more than a hundred institutions in more than twenty five states have already been associated with the airborne astronomy program. *SOFIA will enable new faces, new places, and new ideas to enter the exciting world of space astrophysics.*

The opportunities for educational outreach will, by design, from the very inception of the program, include K-12. The Kuiper Observatory has achieved major successes in this arena, with programs for flying K-12 science teachers on almost every research flight. These teachers rub shoulders with the researchers on board (literally, on the small C-141), and develop lasting links. They return to their students, as well as their schools and communities, the excitement and adventure of scientific research. We have been told by participating teachers that this experience was pivotal in helping them to convey to their students how research is done, and how exciting it can be.

While the Kuiper Observatory, which is based on a military transport aircraft, is neither conveniently deployable to civilian airports nor a comfortable education outreach facility, a Boeing 747 is both of these things. In the course of its science missions, SOFIA will visit major airports around the world, acting as an ambassador of U.S. technology. This deployability will allow schools to have greatly expanded opportunities to visit a NASA facility. SOFIA will bring NASA space science down to earth, and into the communities. *SOFIA will be a reach-out-and-touch scientific facility.*

The operations plan for SOFIA includes a Project Educator position. This will be a leading science educator -- very likely an elementary school teacher -- who can lead and coordinate outreach efforts and develop supporting curricula. This step represents a major departure from the way that government has tried to link research to the educational community in the past. Plans call for cutting edge information and communications technology that will enable schools, planetariums, and science museums to experience the excitement of real-time scientific research through SOFIA.

... International Collaboration and Market Costs: FY96 is a Watershed Year

There are several factors which contribute to the importance of the NASA FY96 request for SOFIA, a request which includes procurement of the aircraft, and start of fuselage modification. *FY96 is a window of opportunity for SOFIA.*

SOFIA is a collaborative effort between NASA and the German Space Agency DARA. In this effort, Germany would bear approximately 20% of the development and operations costs and, in exchange, German space astronomers would receive that fraction of the flight time. We have been given strong indications that this agreement may be perishable, in that postponement of SOFIA development may cost their financial support.

SOFIA would be developed with a used Boeing 747 as a platform. Such used aircraft, with relatively low flight hours and cycles are easily available. The price for these aircraft are at an all-time low, but market forecasts strongly suggest that they will soon rise. Early procurement of an aircraft can also cut runout costs by giving the aircraft modifiers (who are responsible for putting the large hole in the fuselage) a specific target for their efforts.

Postponement of this key phase of the SOFIA effort will greatly increase the cost of the project.

SOFIA and SIRTF: Two Halves of the Infrared "Great Observatory"

As SOFIA builds on the legacy of the Kuiper Observatory, SIRTF, a 0.85-m diameter cryogenically cooled telescope in space, will build on the successful legacies of IRAS and COBE. While the large SOFIA telescope aperture offers the spatial resolution, or clarity, required to resolve small scale structure in astronomical sources (*e.g.* newly born clusters of stars, and the final stages of star formation), the cold SIRTF telescope will, over its 2.5-year lifetime, offer the enormous sensitivity required to see faint and or distant objects (*e.g.* young galaxies in the early Universe, and signposts for the formation of planetary systems). Both facilities will derive much of their power from new sensor technology. SIRTF, in particular, is an opportunity to take full advantage of U.S. technology that was previously developed for the DoD.

SOFIA offers spatial resolution and accessibility, which drives technological advancement, new science opportunities, and education. SIRTF offers sensitivity that is far higher than what we have today. A combination of these capabilities into one observatory is not at all possible in the foreseeable future, and the capabilities of these telescopes are entirely complementary.

Following in the legacies of their precursor observatories, the development of both SOFIA and SIRTF will draw extensively upon the expertise of U.S. industry and universities, working as a team with NASA. During the operations phase, scientific access to these observatories will be granted on a peer-review basis. SOFIA will host more than fifty different investigator teams each year working with approximately fifteen different sensor packages, and SIRTF will accommodate several hundred investigator teams during its 2.5-year life.

... Status

SOFIA has been through several phase B reviews that have produced consistent costings. It is ready for phase C/D development. $48.7M is requested in the FY96 NASA budget in order to support this, out of a total development cost to the U.S. of about (RY) $250M. The first SOFIA research flights will be in 2000. Development of SOFIA is not an R&D project. We know what we have to do, and we build on the heritage of the Kuiper Observatory.

$15M is requested by NASA in the Advanced Technology and Demonstration line for SIRTF. This will be used to complete phase A studies, in order to allow a phase B start in FY97, for a launch in 2001. The total cost of the project will not exceed $500M.

... New Missions and Fiscal Responsibility

Since they were first proposed, costs for SIRTF and SOFIA have dropped substantially, SIRTF by a factor of five, and SOFIA by nearly fifty percent. These cost reductions have come about from sacrifice, technical innovation and creativity. For SIRTF, these latter points include a solar orbit, far away from the heat from the Earth, allowing a smaller cryogen package. For SOFIA, they include reengineering the interface of the telescope to the airplane. These technical innovations have made cost reductions possible, while maintaining most of the science capabilities. It is important to understand that a further descoping of either facility would seriously impact their scientific capabilities. A clear asymptote has been reached.

It is noteworthy that the cost plan for starting SOFIA includes the cessation of Kuiper Observatory operations, which provides a $60M offset against the total SOFIA cost. While the Kuiper Observatory continues to be productive, the importance of SOFIA as the future of airborne astronomy leads us to the very difficult decision to shut down the Kuiper Observatory after SOFIA development is started, but well before SOFIA is ready to fly.

NASA Office of Space Science faces a projected budget decline of about 20% in RY dollars between now and the end of the century. This enormous decline in buying power will be absorbed through missions nearing completion, and by scrubbing raw the MO&DA budgets of the ones that are operating. *Nevertheless, the development of both SOFIA and SIRTF fit entirely within this rapidly declining budget profile.*

Conclusion

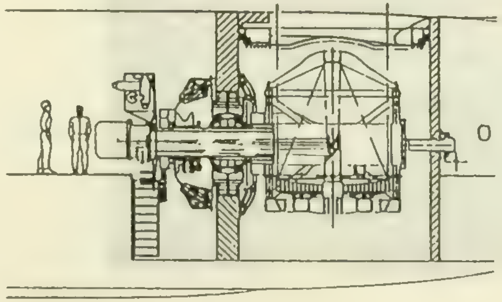
From the point of view of a working scientist out in the community, let me state that SOFIA is not just another NASA space science program. It will be the training ground for the space infrared community of the 21st century. In addition to conducting a program of frontier scientific research, and serving as a driver for continual instrumentation technology development, SOFIA will be designed to serve as a source of inspiration and excitement -- a flagship for U.S. space science. It will do all of this in a highly economical way. In the thousands of miles that it will travel in a single night, carrying its working astronomers, it will invoke the spirit of human exploration that leads us into space.

SOFIA
Stratospheric
Observatory for
Infrared Astronomy
NASA
747
DARA
N747NA
UNITED STATES OF AMERICA
SOFIA
FEDERAL REPUBLIC OF GERMANY

Stratospheric Observatory for Infrared Astronomy
— S O F I A —

Facility

SOFIA will consist of a 2.5 meter telescope operating in a Boeing 747 aircraft at altitudes from 41,000 to 45,000 feet. It will provide astronomers routine access to infrared wavelengths unavailable from the ground, and a means to observe astronomical objects and transient events from anywhere in the world. The concept is based on 20 years of experience with NASA's Kuiper Airborne Observatory (KAO), which SOFIA will replace. SOFIA's wavelength range covers nearly four decades of the electromagnetic spectrum, from the visible, throughout the infrared and sub-millimeter, to the microwave region. Relative to the KAO, SOFIA will be ten times more sensitive for compact sources, enabling observations of fainter objects and measurements at higher spectral resolution. Also, it will have three times the angular resolving power for wavelengths greater than ten microns, permitting more detailed imaging at far infrared wavelengths.



Science

The infrared spectral regime encompasses a multitude of rich and varied physical processes and is uniquely suited for study of cosmic birth on all scales. Questions that would be addressed by SOFIA include:

- *Interstellar cloud dynamics, star and planet formation in our galaxy: What is the nature of collapse, accretion, and outflow processes, and how are they related? How do disks form and what evidence is there for planet formation in these disks?*
- *Origin and evolution of biogenic materials in the interstellar medium and in protoplanetary disks: What environments are hospitable to pre-biotic molecules and compounds?*
- *Comets, planet atmospheres and rings in our solar system: How did our solar system evolve? What was the initial composition of the solar nebula?*
- *Star formation, dynamics and chemical content of other galaxies: How different are the interstellar media of other galaxies? Why do some exhibit extraordinarily large infrared luminosities?*
- *The dynamic activity in the center of our own galaxy: What powers the highly luminous phenomena hidden at the center of the Milky Way - a compact star cluster or a black hole? Is this region similar to the "Active Galactic Nuclei" seen in some other galaxies?*

Program

SOFIA's high spectral and spatial resolution will exploit and extend the scientific legacy of the KAO and IRAS (the Infrared Astronomical Satellite), and will complement the higher sensitivity for imaging and moderate resolution spectroscopy to be furnished by ISO (the European Space Agency's Infrared Astronomical Satellite), and SIRTF (the Space Infrared Telescope Facility).

SOFIA will be developed and operated by NASA and the German Space Agency DARA as an international facility for astronomy throughout a 20-year lifetime. It will provide 160, 8 hour flight opportunities per year for approximately 60 principal investigator teams, selected by annual peer review. Roughly one quarter of these teams will furnish the observatory with state-of-the-art focal plane instruments. In addition, SOFIA will provide important educational opportunities for K-12 teachers, and exposure of this unique astronomical facility to the public. The program has potential for development of commercially applicable technologies, for example in aeronautics and information systems.

Based on its expected contributions to science, technology, and education, the National Academy of Sciences has recommended development of SOFIA as a high priority for NASA in the 1990s. SOFIA has been extensively studied in both the U.S. and Germany, and will begin flying in 2000 if development is started in 1996.

Mr. SENSENBRENNER. Thank you, Dr. Lester. And you hit your fine minutes right on the dot.

Finally, Mr. David Gump, President and CEO of the Luna Corporation in Arlington, Virginia.

STATEMENT OF DAVID GUMP, PRESIDENT, LUNA CORPORATION, ARLINGTON, VIRGINIA.

Mr. GUMP. Thank you, Mr. Chairman. LunaCorp was formed six years ago to find private sources for space exploration.

We planned to put a small satellite into orbit around the moon. It would map the moon's gravity field, and it would also take photographs of the north and south poles, looking for permanently shadowed craters that might contain water.

We met with executives of Coca Cola and Kodak and Pepsi, and solicited their support in exchange for running contests and promotions that they could use to sell their products.

However, in about mid-1991, NASA announced that it was going to place its own small satellites around the moon to map the gravity field, take photographs, and do other activities.

Our potential customers immediately got cold feet, because the things that they had seen positive about our effort suddenly had vanished.

Instead of being responsible for returning to the moon for the first time in two decades to get fresh science, they saw themselves being in competition with the NASA project doing exactly the same thing.

Faced with this, we met with NASA officials, and we pointed out that Congress was in no mood to start a lunar program when it was being continually hit with surprises on the space station budget going up time and again, and we urged NASA to buy the topographic map from LunaCorp on a commercial basis.

We would supply it for about forty million dollars, whereas their own mission was scheduled to cost about a hundred million dollars.

NASA refused to purchase the data from us, and in the end they killed our effort simply with words. It didn't have Congressional funding or authorization for these satellites and never got it, but merely talking about its intention to do the project was enough to squash our initiative.

After this experience, LunaCorp turned to publishing CD ROMs about space exploration and now the profits from the software are helping to support our space exploration work.

Our current project is to land a pair of tele-operated rovers on the surface of the moon in 1998 and, again, the primary customers for this are the entertainment and marketing industries, with also about a third of it being paid for by science researchers.

Dr. Red Whitaker of Carnegie Mellon University is designing the rover for us right now. He is the principal scientist at CMU's Robotics Institute, and the first person to develop autonomous navigation in robots. Meaning, they can pick their own way through a path without human intervention.

NASA supports CMU's lunar robotics with about one point two million dollars a year in support to develop core technologies for lunar rovers. Then LunaCorp will pay CMU to design and build flight-ready incarnations of this technology.

This benefits NASA, because it is relatively small scaled technology funding gets turned into a full scale robotic mission without being a burden on taxpayers.

And we thought it would also benefit us, because with our enabling a NASA-supported researcher, we didn't think that NASA would then turn around and trample upon us again. How foolish we were.

The next year, in 1994, NASA unleashed the draft announcement of opportunity for the discovery program. It was open to proposals for solar system science, including lunar surface science, but the rules for the discovery program prohibited LunaCorp's project from participating.

The rules require that NASA pay the lion's share of the funding for the project. Private support was capped at fifty million dollars, with NASA paying up to two hundred million dollars.

We want to reverse that relationship. We proposed to NASA that we deliver all the science they want for about fifty million, and then have our private customers pay the remainder of the cost, which is a little bit over a hundred million.

We asked NASA to either change the discovery program rules to let a commercially-led mission participate, or simply leave the moon surface out of the discovery program for the time being and not squash us again. We were refused again.

An administrator wrote us to say that they weren't going to leave the moon surface out of the announcement, and just ignored the issue of changing the program rules to allow a commercially-led mission to participate.

When NASA released the winners of the recent discovery round, no surface rovers were funded. So, we dodged that NASA missile this time.

But without a change in policy, plans for private space exploration will remain at risk from future NASA actions.

In our minds, the moon is unique in the solar system for private development and exploration. Its proximity makes it the easiest to reach, and it is the only place where tele-presence—exploration via robotic tele-presence is possible.

There is only a three second communications delay. So, people on earth can use the bodies of robots to explore in real time, and we are banking on a large entertainment market for this ability to help fund our project and create legions of true citizen explorers.

We believe Congress should require that any lunar surface science be supplied by commercially-led missions where NASA is paying less than half the cost.

We are offering to carry payloads for scientists at three hundred thousand dollars per pound, and seven thousand dollars per hour for time. Am I out of time?

Thank you for your agreement to listen.

[The prepared statement of David Gump follows.]

Statement of David Gump
President, LunaCorp
before the
Committee on Science
Subcommittee on Space and Aeronautics
March 16, 1995

LunaCorp was formed in 1989 to find non-government funding for space exploration. The founders believe commercial exploration and development will make the space frontier affordable, and expansion will become self-sustaining as initial profits draw in additional investment. In 1998 LunaCorp plans to conduct the first private lunar mission, and land a pair of teleoperated robotic vehicles on the Moon's surface. Dr. William "Red" Whittaker, Director of the Field Robotics Center at Carnegie Mellon University in Pittsburgh, will design and build the LunaCorp Moon rovers. The primary customers for the mission are from the entertainment and marketing industries, but will include science researchers.

Unfortunately, we face significant obstacles—not arising from technical issues or soliciting private customers—*but from the government*. LunaCorp's first attempt to conduct a private lunar orbiter mission was ultimately undermined by the specter of competition from NASA. Our current plan—a commercial mission which could deliver the science NASA desires for far less taxpayer dollars—is again facing challenge from the very agency which should be supporting such an effort.

LunaCorp's story highlights the fundamental problems with our current space program which assumes NASA control and management of all space exploration and research. What is needed is a paradigm shift which focuses and supports the development of private markets and providers with NASA as a secondary customer—a purchaser of science data when such data can be provided for less than the cost of an entire mission. It requires a new vision of opening up space to the individual: to the entrepreneur, the investor, the citizen-explorer.

Our first project in 1989 was to place a small satellite into orbit around the Moon. Its goal was to provide a good map of the Moon's very irregular gravity field, and to photograph the north and south poles over a period of months to look for two features: permanently shadowed craters that might contain water, and permanently sunlit craters where solar-power panels would be able to function continuously.

Most funding would be provided by companies sponsoring contests and promotions surrounding the first private lunar exploration. We met with executives of Coca-Cola, Kodak, Pepsi and other corporations to pitch the idea.

However, in mid 1991 NASA announced that it was going to launch its own small satellites to the Moon for geochemical, gravity and topographic mapping. Our potential customers immediately got cold feet because many of the positive elements they liked had suddenly vanished. Instead of leading a return to the Moon where their support would bring back fresh science for the first time in two decades, they would be in competition with NASA projects doing the exactly the same thing.

This shows NASA can kill private efforts simply with words. It didn't have Congressional authorization or funding for such satellites; it merely began talking about their possibility.

LunaCorp executives met with NASA officials, and pointed out that Congress was in no mood to start new lunar projects while the projected budget for Space Station seemed to double every few months. We urged NASA to consider buying the topographic map on a commercial basis — purchasing map data from LunaCorp for $40 million rather than attempting to fly their own mission for $100 million.

Through most of 1992, NASA officials said they'd consider a commercial data purchase. In fact, no RFP for this ever materialized. Instead, NASA issued standard study contracts to Boeing and Martin Marietta to look at doing things the old-fashioned contractor way.

At the close of 1992, LunaCorp's commercial customer contacts had gone stone cold and 14 months of talking with NASA about a data purchase RFP had come to naught.

The following year LunaCorp regrouped and began issuing CD-ROM titles about space exploration, starting with **Return to the Moon**. LunaCorp has since formed the subsidiary Lunar Eclipse Software with profits supporting the space exploration efforts.

In 1993 LunaCorp also made contact with Red Whittaker of Carnegie Mellon University. Dr. Whittaker is the principal scientist of CMU's Robotics Institute and the first to develop a robot capable of autonomous navigation. Dr. Whittaker is also the researcher chosen by NASA to receive the agency's lunar robotics funding. NASA supports CMU's lunar robotics effort with $1.25 million a year, with the goal of developing core technologies. Eager to see his robots make the transition from lab to the Moon and with no NASA funding for such a mission in sight, Dr. Whittaker joined with LunaCorp.

To LunaCorp, an alliance with Dr. Whittaker seemed like an ideal situation. We could utilize his shop's existing lunar rover technology and just pay to have him create flight-ready commercial versions. NASA would get to see its small scale tech funding result in a full-scale robotic mission without burdening taxpayers. And not least, LunaCorp would have protection from NASA competition — we did not believe that NASA would trample on one of its own researchers.

How foolish we were. The next year, in 1994, NASA unleashed a draft announcement of opportunity for its Discovery program. It was open to any proposal for solar system science investigation, including lunar rovers. However, Discovery program rules prohibited LunaCorp participation because we were too cheap, and NASA wanted to maintain control. The draft required that NASA pay the lion's share of any project's cost. Private support was capped at $50 million, with NASA paying up to $200 million.

We wanted to reverse that relationship. We wanted to complete NASA's science objectives on a commercial basis, delivering the data sought by scientists for about $50 million. The remainder of the mission's cost—about $100 million—is to be paid by private interests. Despite several meetings where we asked NASA to either leave the Moon's surface out of the announcement, or to change the announcement to permit commercial participation, we were refused. The Administrator wrote us a letter on June 15, 1994, telling us the Moon's surface would not be excluded from the announcement, and totaling ignoring the issue of changing the announcement's rules to permit a mission led by private enterprise.

On March 1, 1995, NASA finally released the winners of this Discovery round. One lunar orbiter was funded. Although proposals were submitted for lunar rover research, none were funded this year. LunaCorp has dodged this NASA missile...for now.

Without a change in policy, our plans to conduct the first private space exploration mission is at risk. It is time for the federal government to pause and rethink its approach to lunar science and exploration. The Moon is unique in the solar system because it is the body most hospitable to private exploration and development. Its proximity means it is the least expensive to reach, and full-scale communications are hindered by only a three-second delay instead of the half hour to several hour delay involved with planetary communications. This is crucial to the issue of telepresence—the Moon is the only solar system body where people on Earth can use the bodies of robots to explore in real time. LunaCorp is banking on a large entertainment market based on this unique possibility to create legions of true citizen explorers. Telepresence also is crucial to commercial industrial work—at first, most lunar workers will have only their robot extensions actually on the Moon, while their human bodies remain on Earth. This will be absolutely key to getting substantial lunar work done within the bounds of affordable budgets.

The advent of this independent return to the Moon can be accelerated by NASA's cooperation or stalled if NASA insists on continuing business as usual. Congress should require that any lunar surface science be supplied by commercial missions where NASA pays less than half of the overall mission cost. That is, NASA must be a secondary customer for a project financed primarily by its appeal to the private sector. It may take several years for such a private project to come to fruition, but waiting until that moment is reached is crucial. We have the bruises to prove that letting NASA run loose will crush private initiatives.

Over the next decade, new launch technologies will greatly reduce the cost of getting into orbit and on to the Moon. At some point, the costs will have dropped enough to permit the financing of a private lunar mission. We at LunaCorp believe we have reached that point already, and will be able to fund our robotic mission in the next several months. LunaCorp is offering to carrying payloads for scientists at $300,000 per pound, and to give exclusive control of a rover to a researcher for $7,000 per hour. Buying by the pound and by the hour gives NASA the flexibility of doing lunar surface science in increments, rather than a whole mission or nothing.

This would also create a precedent for future space policy: NASA acting as a customer rather than a manager when commercial alternatives exist for providing science data. And government working toward supporting private efforts rather than undermining them with tax dollars.

Finally, we would like to point out one area where NASA is doing the right thing. It is an example of a true partnership between NASA, private industry, and local governments —

the NASA Robotics Engineering Consortium at Carnegie Mellon University. As a partner in the consortium, we believe this is precisely the type of participation government should be moving toward.

In the Spring of 1994, NASA's Code X funded with $2.5 million the establishment of the NASA Robotics Engineering Consortium (REC) at Carnegie Mellon University to commercialize advanced robotic technology. The purpose of the consortium was to bring together a critical number of robotics experts under one roof to engineer advanced robotic technology for the commercial sector. Implicit in the agreement with NASA to form this public-private partnership was that NASA's initial grant would be followed up with additional funding if the consortium proved to be successful in the near term.

Based on this assumption, in the intervening months a number of U.S. corporations including LunaCorp have committed more than $30 million in resources. The State of Pennsylvania and the City of Pittsburgh also moved to support the consortium and committed over $8 million of scarce funds to create the REC facility. Construction of the facility will begin next month.

The REC exceeded all of NASA's metrics for success, and NASA's plans to continue funding the REC was included in a program called Robotech 2000. Robotech 2000 would support several initiatives to move lab technology into real-world testing, much the way CMU's Dante robot moved technology from theory into the mouth of an active volcano.

Robotech 2000 was not specifically called out for funding when NASA submitted its budget a month ago. It should have been: much of this funding will go to nurturing an existing but vulnerable consortium that's made remarkable achievements in only a few short months. Carnegie Mellon won very significant contributions from the private sector, the state of Pennsylvania, and the city of Pittsburgh with the expectation that NASA would be able to back its own success. Without NASA involvement and support as the supplier of advanced technology, the consortium model will falter and undermine the credibility of NASA as a sincere business partner.

We urge you to support Robotech 2000 as a very effective new way for NASA-funded technology to reach the private sector.

Mr. SENSENBRENNER. Thank you very much. I would like to thank the panel for some very good testimony. And rather than using my five minutes to ask questions, I would like to make a statement and, perhaps, an explanation of where the subcommittee is at relative to funding the science budget.

It has been the concern of this subcommittee that the manned space exploration programs of NASA, specifically the station and the shuttle, not eat up the science budget, and that there still be a healthy division between unmanned scientific probes, as well as the manned space operations that are funded through NASA.

Last year when we went through the umpteenth reconfiguration of the station, and funding and authorization in an appropriations bill, the concern of both former Chairman Brown, former Subcommittee Chairman Hall, and Mr. Walker and myself were then the ranking minority members of the full committee and the subcommittee, were expressed directly to the President and the Vice President, and following the expression of those concerns, we thought that we had reached an agreement that the OMB would not be chopping away at NASA's budget any more.

Since 1990, when the Augustine Commission Report was released, NASA's budget was reduced both by OMB and by the Congress to thirty percent below the Augustine Commission base line. And because we have got certain fixed cost international agreements with the station, which is extremely high profiled as we know, we were very fearful that if there were further cost over runs in the station utilizing a fixed budget for NASA, the science programs would be completely obliterated, and that was unacceptable to the committee and to the subcommittee, and it still is.

Now, we went past Christmas and New Year's this year on the assumption that while the NASA budget would not be increased, it would be frozen at the level of approximately fourteen to fourteen point two billion dollars, and while there would be no inflation adjustments that we would be able to provide adequate funding for both our manned and our unmanned efforts.

About the 12th of January we got some bad news that OMB had taken another five billion dollars out of NASA over the next five years, and the NASA budget would be reduced to thirteen billion dollars—real dollars, not inflation adjusted dollars—and that caused a big problem.

Mr. Goldin responded to the OMB directive, and that wasn't coming from Congress or Capitol Hill. It was strictly from the OMB.

By appointing a zero based team that was designed to make recommendations on how this cut would be absorbed, and the first draft of those recommendations would be made public on the 17th of May.

The NASA time line indicates that the recommendations will not be finalized until about Labor Day, which is when NASA is required by the OMB to make its initial budget submission for the Fiscal Year 1997 Budget.

When Mr. Goldin appeared before this subcommittee last month to talk about the NASA budget, a number of members of the subcommittee, including myself, attempted to speed up that time line so that we could deal with at least some of those preliminary recommendations before the appropriation bill comes up in the House of Representatives in May or June.

Mr. Goldin responded that he couldn't do that. So, Mr. Gump, we are in the same boat as you. We have been told, no, by NASA as well.

Now, given that scenario, I made a couple of decisions.

First, while I have always been an advocate of a multi-year NASA authorization bill, and had every intention of writing and submitting for subcommittee approval such legislation, it seemed to me that with Goldin's committee working on what is to be done past Fiscal Year 1996, a multi-year authorization bill for NASA would be extremely imprudent, because we would be using with our limited resources what Mr. Goldin has committed a lot of NASA resources to do, and we probably would not have the expertise or the knowledge on how to do it in an intelligent manner.

So, this year's NASA authorization bill is going to be a single year one, much to my chagrin. We do not build aircraft carriers or F-15s with single year authorizations or appropriations, nor should we build space stations or have a long range robotic, scientific space program with single year authorizations.

But I feel somewhat in a straight jacket because of NASA's time line.

Secondly, because there are going to have to be some major hits either on program or personnel, or both, in NASA, it is my belief that this subcommittee should not authorize new start programs such as SOFIA and SIRTF, not knowing if we are going to have the money to complete them.

There have been far too many instances where NASA has sold the Congress on authorizing a program. There have been low ball financial estimates. There has not been any long term projection on whether we would have the money to fully fund these programs to completion, and when the money became scarce, the responsive of NASA and, unfortunately, the Congress, was to stretch out the program's completion date, and that is a sure fire guarantee of a cost overrun, and NASA can't afford any more cost overruns because now that the Defense Department has been so significantly downsized, NASA is the number one target for investigative reporting and we don't want to have to suffer that kind of embarrassment in turning on 60 Minutes or 20/20, and they have an expose on NASA's cost overruns, which we knew were caused by delayed completion date and having the NASA infrastructure on the payroll with the meter ticking, eating up resources.

So, my reluctance to authorize new starts such as SOFIA and SIRTF does not stem from the fact that I don't think SOFIA and SIRTF is good science.

I think it is excellent science. Nor does it stem from the fact that I will sit idly by and watch the manned space program eat up the resources that are available for the unmanned space program.

The fact is that NASA is going to be tipped upside down between now and Labor Day as it has never been tipped before, and once the first recommendations of the NASA zero-based budget team become public on the 17th of May, this subcommittee and this chairman are going to do an awful lot of listening, getting an awful lot of input.

And while I don't think it is feasible given the deficit and the current budget climate that we will be able to increase the total amount that goes to NASA, that doesn't mean that we are going to sit back and rubber stamp what Mr. Goldin comes up with.

The gentleman from Florida, Mr. Weldon.

Mr. WELDON. Thank you, Mr. Chairman. I have no questions at this time.

Mr. SENSENBRENNER. Well, thank you very much. On that happy note, I would like to thank all of the witnesses for coming, and the subcommittee is adjourned.

[Whereupon, the subcommittee is adjourned at 1:53 p.m.]

APPENDIX

Responses to written questions submitted by Chrm. Sensenbrenner resulting from the February 13, 1995, hearing.

BASIC SCIENCE

Question 1: How does NASA determine the appropriate mix of funding between basic science funding (R&A and MO&DA) and acquisition of new spacecraft assets?

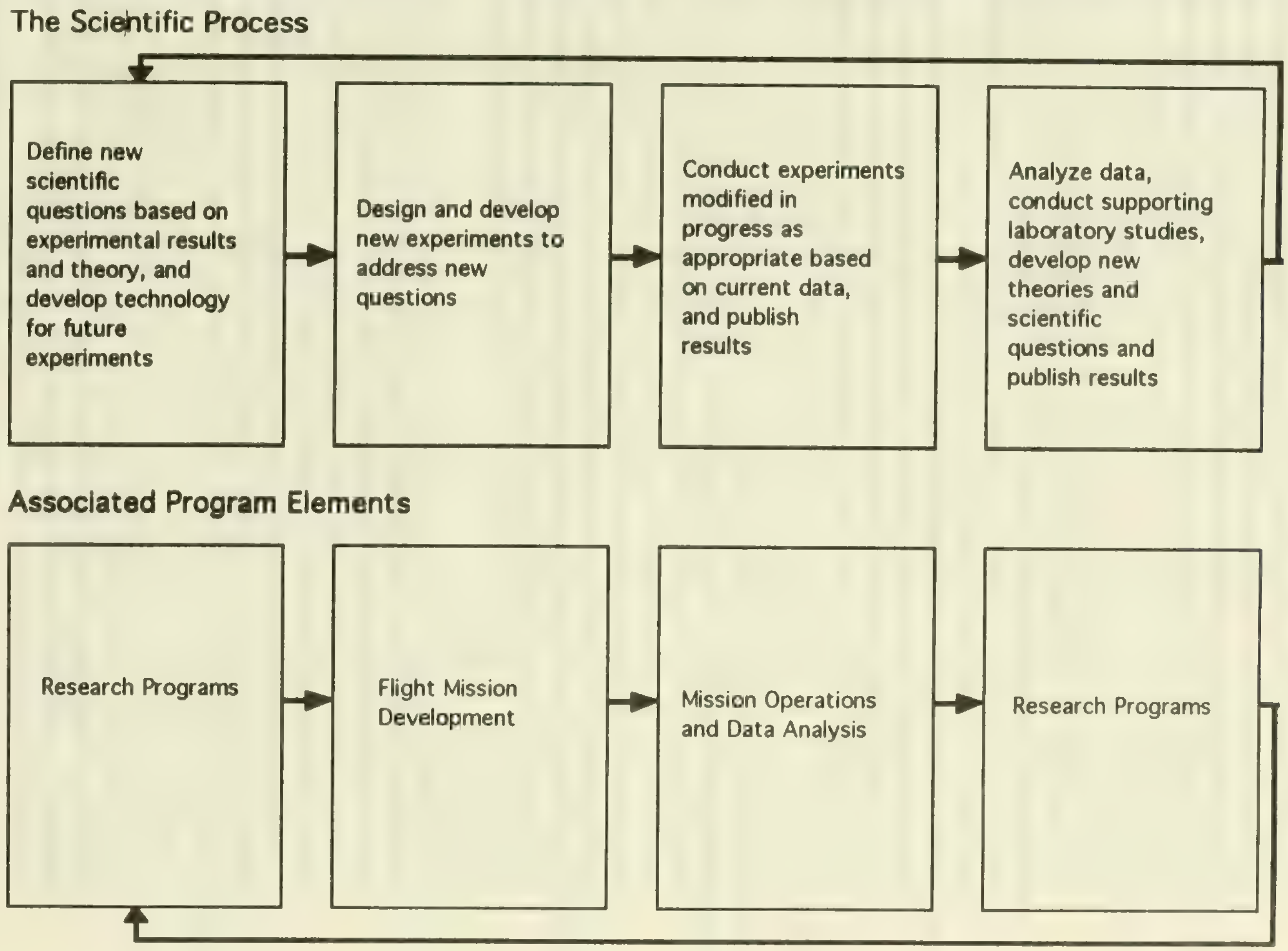
Answer 1: As a result of the overall NASA budget situation, the Office of Space Science (OSS) has capped the budget for R&A at the 1994 level. MO&DA levels in recent years have been dependent on two factors: the number of missions in operation and reinvention activities aimed at reducing operations costs to create funding opportunities for new missions.

In OSS, the highest priority remains completing the approved program (those missions in operation or under development) with a disciplined commitment to defined cost envelopes. Missions in operation have been reviewed extensively over the last 2 to 3 years to ensure that we are operating them as efficiently as is safely possible. The identified savings, coupled with funds reallocated within the Agency, have been reinvested in new initiatives proposed in the FY 1996 budget request. These new initiatives illustrate the significant realignment that is taking place in all aspects of the space science program:

- The shift toward more frequent access to space is embodied in the proposed continuation of the Discovery program of small, lower cost planetary missions, and the proposed new start of the Stratospheric Observatory for Infrared Astronomy (SOFIA).
- Preliminary activities in support of a future new start for both the Space Infrared Telescope Facility (SIRTF) and our participation in the European Space Agency's Rosetta mission. The current total cost for the SIRTF program has been reduced by almost a factor of five compared to the original 1991 cost estimate.
- The dedication toward preparing a future for space science is also embodied in the requested new start for the New Millennium program. This program will emphasize innovative mission concepts and associated technology development activities in cooperation with the Office of Space Access and Technology (OSAT) and the Office of Mission To Planet Earth (OMTPE) to achieve space science goals for the year 2000 and beyond. The New Millennium program will provide for the development and flight validation of key technologies for future space science missions, permitting us to do more science with smaller and less costly spacecraft.

New missions are the life blood of space science. NASA's program is based strongly on the scientific method and certain program elements correspond to different stages in the scientific process. Science advances are made through a series of steps, each of which is crucial to the overall health of the scientific enterprise. The first step is to define new scientific questions based on experimental results and theory, and to develop the advanced technologies needed for future missions. In the OSS budget, the R&A program fulfills this role.

Space Science Structural Elements


The Scientific Process
Define new scientific questions based on experimental results and theory, and develop technology for future experiments
Design and develop new experiments to address new questions
Conduct experiments modified in progress as appropriate based on current data, and publish results
Analyze data, conduct supporting laboratory studies, develop new theories and scientific questions and publish results
Associated Program Elements
Research Programs
Flight Mission Development
Mission Operations and Data Analysis
Research Programs

The next step is to design and develop new experiments to address the latest scientific questions. The flight mission development activities achieve this function. Next we conduct these experiments, modifying them while in progress as appropriate based on current data, and then publish the results. The MO&DA portion of the OSS budget request is responsible for this activity.

The last step in this process is to analyze the data, conduct supporting laboratory studies, develop new theories and scientific questions and publish the results. This aspect is also covered under the R&A portion of the budget. Once this fourth step is complete, the process is repeated, building upon past accomplishments to increase the body of knowledge. This concept is graphically represented by the attached chart.

It is important to note that the desire is to create an effective balance between all elements of our program -- to ensure that we get as much science as is possible out of our missions in operation, to make sure that this information is appropriately analyzed and published in the scientific community (and presented to the American people), and that the technologies necessary for future missions are properly started. Without this balance, the scientific process cannot work and the body of knowledge we are striving to enhance will fail to expand. New missions are the crucial step in this process because they are perpetuate in the cycle of discovery.

This balanced space science program is the result of the strategic planning process within OSS. Every three years, we update our strategic approach to ensure our goals are consistent with the current budgetary and political environment. And approximately every three years, we publish a new OSS Strategic Plan which outlines our priorities and goals for the next five years. This plan is developed through the active participation of the scientific community and is reviewed by the Space Science Advisory Committee (SSAC), composed of preeminent scientists from various institutions around the country involved in space science. It details the scientific communities highest priorities for new space science missions.

Each year NASA develops a budget request based on the NASA strategic plan and the strategic plans of each respective Strategic Enterprise. In the OSS process, we treat approved missions (in development or in operations) as the highest priority and we plan to support a mission through its primary mission. Continued operations beyond the primary mission are treated as if they were new starts, and are peer approved in competition with other new starts to ensure that a proper balance between new missions and existing mission is maintained.

Question 2: In the Budget proposed, NASA will continue an ongoing series and start a series of smaller spacecraft missions: the Discovery, Explorer, and New Millennium missions. What percentage of the budgets for these new vehicles is devoted to getting science from them? Are we over-building spacecraft compared to our ability to fund the science these spaceships will do?

Answer 2:	% Instruments of % MO&DA	total development of total mission cost
Explorers	30-40%	10-20%
Discovery	10-20%	10-20%

The purpose of the New Millennium program is to demonstrate technologies for future science missions which will reduce mass, power, and cost requirements. NASA intends to capture scientific data with these spacecraft, but the primary goal will be to demonstrate technologies which will benefit the science missions of the future. The technologies developed and flight tested through the New Millennium program will be incorporated into NASA's Earth and Space Science missions planned for the year 2000 and beyond.

Question 3. Will the New Millennium Program duplicate any advanced technology efforts that the Strategic Defense Initiative Organization (SDIO) engaged in?

Answer 3: The New Millennium program will not duplicate efforts. We anticipate that the program will instead develop a synergistic relationship with technology providers. The New Millennium program is being designed to seek technology validation from all sources, including industry, academia, and other government agencies.

NASA's Jet Propulsion Laboratory (JPL) will manage the New Millennium program. JPL has a long and productive history of working with the Department of Defense's Ballistic Missile Defense Organization (BMDO), and its predecessor the Strategic Defense Initiative Organization. JPL's efforts in microspacecraft definition for planetary missions has for many years made use of BMDO and SDIO technology concepts and ideas. JPL has also played an active role in several BMDO missions. The New Millennium program expects to benefit from a number of technology development activities that were supported by BMDO/SDIO and, in some cases, will continue to be supported by BMDO.

For example, as part of the BMDO Space Technology Research Vehicle program (STRV), long Wavelength Infrared (LWIR) detectors, neural net computer chips, and cooler technologies were developed at JPL for BMDO and NASA. In addition, on-chip radiation monitors were developed at JPL under contract to the Department of Defense (DOD).

These on-chip radiation monitors were further developed at JPL, again under contract with the DOD as part of the Clementine mission. JPL also tested, selected and assembled a variety of electronics and charged-coupled device (CCD) technologies to support this mission.

JPL also has developed the prototype high temperature supercomputer bandpass filter for BMDO and the Naval Research Laboratory (NRL) as part of the High Temperature Superconductor Space Experiment II. JPL is currently integrating the flight hardware for this important part of the low-noise microwave receiver subsystem for this mission.

In summary, specific technologies that have been developed at JPL under BMDO funding or co-funding include the following:

- Micro-Electric-Mechanical Systems (MEMS)
- Tunnel sensors (accelerometer, far infrared sensor, magnetometer, gyroscopes, etc.)
  Additional sensors (seismometer, thermodynamic sensors, etc.)
- Electron-beam lithography

- * Silicon-compatible LWIR detectors (heterojunction internal photemission detector, wavelength extension of Platinum-Silicon detectors)
- * Quantum Well Infrared Photodetector (QWIP), III-V LWIR detectors
- * Delta-doped CCD extension to ultraviolet, x-ray and particle detection
- Thz sources and high speed devices
- High temperature superconductor devices for communications and sensors
- Diode lasers and photonics for optical communications, optical computing, photonic instruments
- Optical processing using holographic optics for image processing and target recognition
- * Neural Networks
- * Vertical Bloch line magnetic memory (Primary facility for all of DOD)
- Wide bandgap materials for ultraviolet sensors, as well as high temperature and radiation-hard electronics
- Silicon-based Optoelectronics
- * Coolers for space, including testbed
- * Cryogenic electronics, including testbed
- * Electric propulsion
- * Supercomputing, including hypercube development

* = JPL serves as BMDO's primary facility for these activities.

Question 4. Are you currently conducting joint programs with the Department of Defense (DoD) in lightweight spacecraft (i.e. Millennium, Lewis and Clark, Discovery)? Does NASA have any managers formerly with SDIO who have direct experience with lightweight technology?

Answer 4: NASA's Office of Space Science is not currently collaborating on joint, lightweight space science programs with the Department of Defense.

As mentioned below, several BMDO/SDIO personnel have freely shared the technologies and processes used on BMDO/SDIO missions with NASA and JPL personnel. In addition, many of the managers at APL and JPL that have worked on BMDO/SDIO missions to develop these technologies and processes are involved with the Discovery and New Millennium programs.

Question 5. Have you ever given consideration to making use of the space technology group in the Ballistic Missile Defense Organization (BMDO) by subsuming the group into NASA? BMDO's space activities have demonstrated the mantra that you preach faster, cheaper, better. Would it not make sense to make use of this expertise?

Answer 5: The goal of revolutionizing NASA's approach to spacecraft missions has to go beyond a certain group of individuals. To be successful in the long-term, change must be institutionalized throughout the organization. NASA's approach has been to work closely with DOD on missions like Clementine, to learn from them what we can, and to incorporate these lessons throughout our programs.

NASA is taking full advantage of one of the most powerful technology transfer mechanisms, people. Colonel Pete Rustan (USAF) and Dr. Stewart Nozette, key players in the Clementine mission, are unselfish in their sharing of information about technologies, processes and experience. In addition, the Naval Research Laboratory's Paul Regeon serves on some of our independent Near Earth Asteroid Rendezvous (NEAR) and Mars Global Surveyor (MGS) flight program independent reviews. In addition, as mentioned above, significant numbers of JPL employees have served as technology developers on BMDO-funded activities in a variety of areas.

NASA also studied Clementine operations very closely. Matched with our experience in the final months of Magellan (where we operated the spacecraft with significantly fewer operations staff than were used at earlier periods in the mission), NASA and JPL have already incorporated what we have learned from these missions into the operations design of our upcoming space science missions. It is in this area that we expect to see the most significant improvements as a direct result of the Clementine and Magellan missions.

Question 6. What are you doing to incorporate the Clementine team into NASA (experts and facilities)? Are you duplicating this capability in programs like Discovery?

Answer 6: The Discovery Program is not duplicating the Clementine experience, but rather using some of the same resources to improve our approach to space science missions. In the Discovery Program's NEAR mission, being developed at Applied Physics Laboratory/Johns Hopkins University, the spacecraft is using a derivative of the Clementine laser radar transmitter from the same industrial supplier. In fact, in the Discovery Program we are using some of the same Ballistic Missile Defense Organization (BMDO) management techniques and technologies, facilities, and people resources used in the DC-X program. NEAR has one Headquarters Program Manager and the Project Manager is the contractor, the Applied Physics Laboratory. As you will recall, the Applied Physics Laboratory was on the BMDO cutting edge of quicker, cheaper, faster missions with Delta 180, 181, 183, and JANUS. The same APL team, management techniques, and facilities are being used on NEAR.

The Mars Pathfinder project at JPL has benchmarked the Applied Physics Laboratory/Johns Hopkins University and the Naval Research Laboratory's approach and operations of Clementine. Benchmarking is a management technique that is central to the Total Quality Management (TQM) approach. These benchmarks are being used against Mars Pathfinder development and operations. The Mars Pathfinder had started development before the Clementine launch and demonstration of technologies, so the infusion of technology was mostly in the operations area.

Further, the recently announced selections for the Discovery missions are good examples of how NASA has incorporated lessons learned. The first principle in the Discovery program is to provide opportunity -- to open up planetary science and exploration to ideas from outside NASA. We accomplished that goal by soliciting mission proposals from the general science and aerospace community, rather than defining the mission here in NASA. These proposed missions are not NASA-defined and executed missions, but rather, are missions defined and executed by the aerospace and science community.

At NASA, we have turned the old way of doing business upside down. The old way had the scientific community supporting NASA missions. Under this new paradigm, each proposer is expected to pull together a team (that may or may not include NASA Center participation) that fits their interests. In the Discovery program, NASA is in essence purchasing missions from the university and aerospace community. Discovery missions are to be managed by a single Principal Investigator (PI) allied with a university/industry/Federal Center team, and that PI is solely responsible for the mission.

The second principle in the Discovery program is competition. Competition is essential to getting the greatest possible science return for the least expense of taxpayer dollars. In Discovery, NASA will no longer make direct assignment of missions to Federal centers. Discovery missions are open to the widest possible range of bidders in order to ensure an open competition. There are no entitlements in this program for NASA Centers or other government centers. Each participant must earn the privilege to participate in these exciting new missions in face-to-face competition through the peer review and selection process. This ensures that and the American people get the best possible science return on their investment.

SPACE STATION

The Space Station program was specifically exempted from the January 12 OMB-directed reductions for the out-year spending profile.

Question 7: Why was the space station exempt from these across the board reductions?

Answer 7: The Administration and the Congress have challenged federal agencies to streamline operations and improve the efficiency of federal programs. In response to this challenge, NASA has initiated a review process to identify options that will enable the agency to streamline, yet perform its vital functions within the available resources.

In 1993, the international Space Station program was redesigned to achieve world class science at a lower cost to the American taxpayers. Further, NASA also reduced the number of Space Station employees -- both civil servants and contractor support -- involved in management and integration by approximately 50 percent. The program was redesigned to meet the Administration's goals for the National Performance Review of better government at a lower cost to the taxpayer.

The Administration removed the Space Station from the outyear reductions based on this previous restructuring. However, the Space Station program continually looks for ways to improve its efficiency and we will continue to look for cost savings.

Question 8: Who is liable for a failure to perform under the terms of the protocols for the FGB?

Answer 8: There are two sets of protocols concerning the FGB. The first one is between Lockheed and Khrunichev, and the second one is between NASA and the Russian Space Agency (RSA). It should further be noted that the protocols are just preliminary memoranda of negotiation between the parties and are not considered legally binding. The contractual documents which define roles and responsibilities, as well as terms and considerations, are being drafted to reflect the protocol agreements. Under the signed protocols and pending contracts, responsibilities and liabilities are defined as follows:

1. Khrunichev, through a fixed price contract from Lockheed, is responsible for the FGB performance through pre-launch.
2. RSA, through the combination of the $400 million contract from NASA and its contributions as an international partner, is responsible for the successful launch of the FGB.
3. Lockheed, through its cost-type contract from Boeing, is responsible for the on-orbit performance of the FGB for the first 15 days on-orbit. Lockheed's recourse is to Khrunichev.
4. RSA is then responsible for the successful on-orbit operations and the necessary maintenance of the FGB throughout its useful life in support of the Station program.
5. Boeing, as the prime development and integration contractor for NASA, is responsible for the accurate and timely flow-down of system and performance and interface specifications.

Question 9. Is Boeing under contract to assure the FGB is on-orbit in November 1997? Is Lockheed responsible?

Answer 9: Boeing is under contract to assure the timely and successful on-orbit performance of the FGB. Lockheed, as subcontractor to Boeing, is responsible for the development, manufacturing, testing, delivery, and on-orbit (15 days) operations of the FGB.

Question 10. When does ownership transfer from Khrunichev to Lockheed, from Lockheed to Boeing, from Boeing to the U.S. taxpayer?

Answer 10: It is currently contemplated that title to the FGB will pass from Khrunichev directly to the U.S. government as the intended third party beneficiary of the Lockheed/Khrunichev subcontract. The specific timing of when ownership will transfer to the U.S. is the subject of on-going discussions, with the outcome dependent on final decisions concerning the logical technical and operational subcontract performance milestones.

SPACE STATION UTILIZATION

Question 11: Of the $1.3 billion budgeted for operations on space station, what percentage has been reserved for scientific efforts?

Question 12: What percentage of the $1.3 billion has been reserved for commercial or manufacturing-relating efforts?

Question 13: What percentage of the $1.3 billion will be devoted to "Housekeeping" costs, such as maintaining electric systems, refueling costs, etc.

Question 14: Is the space station hardware designed to operate within these approximate cost limits?

Question 15: In your opinion, what percent of the $1.3 billion would be too high for "Housekeeping"?

Question 16: What is NASA's cost goal for "housekeeping" expenses, versus utilizing the facility?

Answer 11-16: The $1.3 billion annual budget for steady state operations was established during the Space Station Redesign activity as the yearly average of $13 billion over a 10-year life. At that time, the budget for payloads was estimated to average about $180 million a year, with another $120 million in utilization support. Total ground and vehicle operations (including housekeeping) was set at $700 million, with the remainder of the $1.3 billion budgeted for Space Shuttle integration, institutional costs, and reserve.

Currently, a major effort is underway to study Space Station operations and utilization consolidation as part of NASA's overall downsizing exercise. NASA is reviewing requirements both within the Station program and between the Station and Shuttle programs. Given this activity, it would be premature to cite and defend estimates which are presently under scrutiny and will most certainly be revised over the next several months.

Question 17: Is NASA's reduced flight rate of seven Shuttle missions per year based on the high cost of each flight, or is it more a function of reductions in personnel that have taken place to date and those which will come over the next year?

Answer 17: The decision to reduce the shuttle's flight rate to "an average of seven flights per year" was, in part, a budgetary decision based on the amount of funding that can be expected over the FY 1996 budget horizon. It is also a flight rate that is congruent with the requirements of the space station assembly sequence scheduled to begin in early FY 1998.

Question 18: In view of the reductions in personnel that are ongoing, if the workforce within the Shuttle program is right-sized to meet an annual launch rate of seven per year, will contingency plans to increase the launch rate to eight or even ten launches jeopardize safety?

Answer 18: For the long-term, the Space Shuttle Program workforce has been sized to meet a sustained flight rate of seven flights per year. Within a single year, however, eight flights could be handled by the current workforce using overtime. With the current workforce it would be extremely difficult to fly ten flights per year without "breaking" our existing overtime constraints which were established to assure safe flight processing conditions. In addition, our production of major hardware components has been sized for an average of seven flights per year. Currently, we have no contingency plans for a major ramp up of flight rate beyond eight flights in a single year.

Question 19: Are you closely monitoring the skills and experience levels of those who are choosing to take buyouts in order to ensure that safety and efficiency are not being sacrificed?

Answer 19: There is always a concern that mission critical personnel could leave us short of the proper skills and experience and jeopardize the safe and efficient operation we currently enjoy. The NASA Administrator has also expressed concern about the issue of losing Shuttle personnel with mission-critical skills to the buy-out without adequate backfill capabilities. In a letter dated, February 21, 1995, he stated, "I will only approve requests for (Buy-Out) extension to those few individuals who perform mission-critical functions which cannot immediately be picked up by other employees." This will reduce the likelihood of losing those mission critical personnel who wish to take the buyout until replacements can be trained to take over their positions.

Question 20: Are future buyouts being targeted to those areas which are over strength and correspondingly being denied to critical skill and experience levels? I am concerned that NASA's personnel cuts and buyout program might be using more of a "shotgun" approach rather than a more closely targeted plan.

Answer 20: There are no plans to conduct future buyouts after the current one expires on March 31, 1995. The results of the current buyout and its impact to the workforce in terms of the level of skills and experience remaining will dictate the degree to which we must target areas for further reductions. The Shuttle Program is closely monitoring the buyout volunteers to ensure mission supportability. Those who are mission-critical will be identified to the NASA Administrator for extension requests.

Question 21. Recently, three senior NASA officials (Mr. Crippen, Gen. Pearson and Mr. Utzman) have left the Shuttle program and there have been questions raised about the program being jeopardized by personnel cuts too deep, too fast.

What assurances can you give us that the Shuttle program will be "right-sized" responsibly with the advice of those in the field - the operators - and not subjected to pressure to meet a budget bogey?

Answer 21: The Space Shuttle Program recently completed a series of "Functional Workforce Reviews" of the major Shuttle contractors and the civil service workforce. The reviews were conducted between August 1994 and February 1995. The purpose of the reviews was to identify the minimum workforce necessary to safely fly seven Shuttle flights per year. As we approach the implementation phase of this effort, we have been careful to place several safeguards into the process to assure that we aren't unduly subjecting ourselves to budget pressures.

First, each Functional Workforce Review recommendation was accompanied by feedback and reclama from both the contractor and the government Project Managers. Second, implementation of the recommendations has been left to the Center Directors discretion, in consideration of the total workforce reductions to be taken at each single location. Third, the Center Director's were given latitude to take workforce reductions in other areas than those recommended by the teams. Fourth, monitoring the progress of these implementations will be a continuing process by the Office of Space Flight Management Council (Office of Space Flight Center Directors and the Shuttle Program Director). Finally, the Functional Workforce Review results have been given to the individual Project Managers to assess again during the annual budget formulation process that began this month.

Question 22. Following the Challenger tragedy, the Shuttle flight schedule was suspended as necessary changes were instituted. Today there is discussion of consolidation of Shuttle work under a single prime contractor in order to increase the overall efficiency of the program. Your upcoming flight schedule is ambitious from the standpoint that so much has been compressed into a reduced annual launch rate.

Would consolidation under a single prime contractor in the midst of this expose the program to risks which are disproportionate to projected savings?

Answer 22: The Shuttle Program is looking at the possibility of using a single prime contractor as one of several potential options to save cost without affecting risk. In general, the Shuttle Program is studying the benefits and impacts of assigning more responsibility and authority to the contractor workforces and reducing the involvement of civil service personnel in the day to day management of its more mature operations. In any case, a carefully planned transition strategy will be the key to successful change.

Question 23: Are you satisfied that the level of input from the field has been adequate in formulating changes in the Shuttle program?

Answer 23: We are satisfied considering where we are in the overall process. To date, the various study results have been presented with significant lead times and at a high enough level that we believe we have ample time left to take care of the significant coordination process ahead of us. There is currently a plan to formulate a strategy for implementation of the various team's results. This strategy will receive wide internal distribution for review and comment. We will also be continuing to fold top level strategy into our budget formulation process where the various levels of the organization make their input and recommendations.

Question 24: In your Shuttle program brief for FY 1996, an item listed as being a significant change since the FY 1995 budget is "reduced flight crew ops workforce by reducing levels of oversight. Can you explain in greater detail what this means?

Answer 24: The Flight Crew Operations Division at JSC maintains and operates the shuttle's fleet of training aircraft at the Ellington Air Base in Texas. The contract for this effort was recompeted in 1993 with a statement of work that reduced the number of personnel required to perform the maintenance function from 250 to 230. One year later, the contractor has met that challenge primarily by reducing oversight and specialization. For example, the maintenance department personnel complement was downsized by the creation of "production inspectors" who, in addition to their primary function of performing maintenance, now also inspect other employees' work. Thus, the existing cadre of personnel whose only function was to inspect others' work was eliminated.

In addition, through cross-training and certification, employees are now qualified to work on more than one section of the aircraft. This was accomplished through joint cooperation with JSC management, local unions, and the contractor, Dynacorp. The result is that not only has the size of the workforce been reduced, the morale of the organization has increased.

Question 25: Given all the reviews which have already been conducted and those which are still ongoing - both internal and external - and the pending personnel reductions, how would you characterize the present morale of the agency?

Answer 25: The morale of employees working within the Shuttle program, both contractor and civil service, is always a concern to program and project managers. The numerous reviews, white papers together with impending budget and personnel cuts have predictably caused various degrees of uncertainty for the workers. OSF management are striving to keep communications open and information flowing as decisions regarding streamlining and reorganizations become more concrete. Managers are also closely monitoring performance metrics such as, problem reports, in-flight anomalies, and quality escapes to measure any negative performance trending.

Question 26: What steps are you proposing to ensure that over the next two years that the level of uncertainty of NASA employees is reduced?

Answer 26: The OSF managers are planning to make decisions regarding any downsizing or reorganization efforts in a timely manner, keep communication lines open and focus on flying the Shuttle safely.

Question 27: Will ongoing personnel reductions increase the length of time required for an orbiter to complete an OMDP, to include the preparations before and after the OMDP. If so, will there be any net effect on the future launch schedule?

Answer 27: A small decrease in personnel would only increase the OMDP schedule risk. A larger personnel reduction would increase the amount of time required to process the Orbiter during OMDP related activities. Reductions over the last few years at KSC and Palmdale have resulted in increases in the OMDP processing times. Neither these, nor any reductions envisioned in the future, however, are expected to reduce the flight rate to below seven flights per year.

Question 28: Has the peer review process for scientific experiments to be performed on-orbit become too lengthy and cumbersome, thereby adding unnecessary expense to the overall cost of the program? Can savings and greater efficiency be realized by streamlining the peer-review process for on board experiments?

Answer 28: No, the problem is not related to peer review. The changes in our peer review process to select the best science and to prevent conflict of interest we now have in place have been praised by our oversight committees and the scientific community at large. Attached is the report from the Federation of American Societies or Experimental Biology (page 42) noting the excellent results in our peer review process.

Flight experiments are a rare and precious opportunity. Peer review is necessary in order to insure the highest quality research. We have instituted a program for selecting research on a continuum from ground to flight. This insures that only after everything has been tested and studied on the ground will the research experiment graduate to a flight opportunity. Using this process we have been able to shorten the time from peer review and selection to flight to as little as three

FASEB

Federation of American Societies for Experimental Biology

The American Physiological Society (APS)
American Society for Biochemistry and Molecular Biology (ASBMB)
American Society for Pharmacology and Experimental Therapeutics (ASPET)
American Society for Investigative Pathology (ASIP)
American Institute of Nutrition (AIN)
The American Association of Immunologists (AAI)
The American Society for Cell Biology (ASCB)
Biophysical Society
American Association of Anatomists (AAA)

Consensus Conference on FY 1996 Federal Research Funding in the Biomedical and Related Life Sciences

Report

National Aeronautics and Space Administration

Agency Mission and Life Sciences Programs

The National Aeronautics and Space Administration (NASA) Life Sciences program is unique — it is the only federal program that conducts medical research in space. Microgravity in space allows exploration of fundamental biological questions that are impossible to study on Earth, including how living organisms sense and respond to gravity, the role of gravity in growth and development, and the influence of gravitational changes on biologic processes. The scope of this research is broad: studies are conducted at molecular, genetic, cellular, and organ levels, in plants, animals, and humans. The distinctive characteristics of space offer opportunities to advance understanding of a myriad of biological processes, and to apply the new knowledge gained to improve the quality of life on Earth.

Access to space enables NASA Life Sciences to approach medical and scientific issues and problems from an unusual perspective. With its space and related ground–based research programs, NASA is providing new insights into important areas of medicine, including cardiorespiratory, immune, body fluid, and endocrine regulatory mechanisms, and such medical problems as bone demineralization, fractures, wound healing, muscle atrophy, and disorders of balance.

Recent Accomplishments

Examples of recent NASA accomplishments in life sciences research include:

- NASA life scientists and NIH epidemiologists examining the use of remote sensing maps to identify areas of the globe where conditions favor growth of mosquitoes and malarial parasites

- NASA and National Cancer Institute scientists applying NASA's expertise in digital imaging to interpretation of mammograms

- Experimental data obtained during Space Shuttle missions refuting predictions based on ground– based bedrest research, that weightlessness increases pressures in the great veins of the chest. Actual measurements obtained from astronauts launched with catheters connected to pressure gauges indicate that pressure in central veins is lower in space than on Earth, not higher

- Also against expectations, actual measurements from space indicating that the imbalance present on Earth between blood flow to the highest and lowest lung segments persists in space.

National
Aeronautics
and Space
Administration

The Conferees were impressed by the great strides NASA Life Sciences has mad in improving its peer review of research As of this year, all research proposa submitted to NASA, from intramural as well as extramural scientists, underg the same process of competitive peer review. Preliminary analyses of these swee ing changes indicate that NASA has expanded its research opportunities to much larger and more diverse segment of the scientific community than befor We expect that these changes will have significant and positive effects on th quality of NASA's Life Sciences research efforts.

The Conferees are enthusiastic about the collaboration between NASA an NIH. NASA and NIH have made great progress in preparation for their jointl sponsored Neurolab Spacelab Space Shuttle Mission, scheduled to occur durin the Decade of the Brain. Since the last FASEB Consensus Conference Repor special NIH peer–review panels constituted for the Neurolab Mission have s lected proposals submitted by a highly respected group of neuroscientists

> *"FASEB opposes using biological research as a major justification for the space station. If Congress or the Administration feels that a space station is important for a national prestige, then physiological research sponsored by NASA to maintain the well–being of astronauts is warranted."*
> FASEB Public Affairs Executive Committee. (April, 1994).

The Conferees believe that all of NASA's mission programs should be accessib as appropriate, to Life Sciences research. For example, NASA should fully use r search opportunities afforded by the series of Mir Space Station–America Space Shuttle docking missions, scheduled for the last half of this decade. Tl Conferees share the concern of the National Research Council (NRC) Spa Studies Board that (excepting the Neurolab Mission) NASA is abandoning Space Shuttle Spacelab Life Sciences research program, which has proved value, in favor of the uncertain promise of future research on the Russia American Space Station.

Policy Recommendations

In view of the improvements made in the Life Sciences program, NASA shou transfer all its Life Sciences research activities and their budgets to the Life a Biomedical Sciences and Applications Division. This includes transfering search involving life in extreme environments, currently in the exobiology p gram, and the Aerospace Medicine program.

Budget Recommendations

To enable NASA to maximize the benefits of its greatly strengthened peer revi and its collaboration with other federal agencies, we recommend that the L Sciences budget be restored to the FY 1994 level, $53.8 million. Further, the Co ferees recommend that the level of FY 1996 funding for NASA–NIH collabo tion be increased from $15 to $20 million, and that at least $10 million of tl be allocated for the Life and Biomedical Sciences and Applications Division.

National
Aeronautics
and Space
Administration

TABLE 9: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Life Science Funding and FASEB Recommendation
Fiscal Years 1994-1996 (Dollars in Millions)

Program	FY 1994	FY 1995	FY 1996	
	Appropriation (Actual)	Appropriation	FASEB Recommendation	% Change from FY 95
Life Sciences and Biomedical Applications Division, Research & Analysis	$53.800	$50.700	$53.800	6.0%

months in the case of the NASA/NIH cell culture experiments and as little as two months for human Extended Duration Orbiter Medical Program. We are working to make this the rule rather than the exception. The limiting time factor for flying a peer reviewed research investigation will then be crew training.

Question 29: Has NASA determined the minimum contractor labor force required to safely operate the Shuttle at the current flight rate, given current processing requirements?

Answer 29: Yes. This was a prime objective of the recent Space Shuttle Program Functional Workforce Review.

Question 30: If further efficiencies cannot be found without compromising safety, what flight schedule and manifest changes can be made to meet the cost targets in view of the station launch and assembly requirements, as well as other demands for the shuttle?

Answer 30: A reduction in the current flight rate is inconsistent with today's Space Station and Shuttle based science requirements.

Question 31: Only 3 of 4 orbiters will be available to support space station launches because the shuttle Columbia is too heavy. In addition, due to normal maintenance scheduling, there will be times when only two orbiters will be available.

Answer 31: There will always be three Orbiters available to support the manifest, but there will be times when there will be only two Orbiters available to support Space Station.

Question 32: If NASA continues to fly the Shuttle at the rate of seven flights a year, what is the justification for maintaining three orbiter processing facilities at KSC? Could one of those facilities be used for performing modifications to the orbiters?

Answer 32: Two OPF bays are required to process orbiters for flight. The third is used to prepare for and recover from Palmdale OMDPs. Currently, the pre and post OMDP activities tie up a bay for 70 days (preparation) and 130 days (post OMDP processing) or a total of 200 days per OMDP. Finally, post- landing safing operations are of high priority and are accomplished seven times per year in whichever bay is most available. This operation usually takes about 10 days.

OMDPs could be accomplished at KSC, saving approximately four months of down time each, with the primary savings coming from the reduced preparation and post OMDP processing time. This extra availability would provide more long-range manifesting flexibility. The down side, however, is that there would be occasional cases at KSC where all three OPF bays are occupied at a time when the fourth orbiter, having just landed, needs a place to be safed. This situation could perturbate the OPF schedule for one of the flight orbiters.

Question 33: How are the flight programs related to each other?

Answer 33: The three X-vehicle programs are intimately interrelated. In the spirit of "crawling before you walk and walking before you run" each program builds on the other. Thus, the DC-XA program is the tool through which the BMDO-developed technology and management philosophy will be transferred to NASA. It will also permit early, small scale demonstration of advanced technologies (e.g. reusable cryogenic tankage, composite primary structures) in a flight environment.

The X-34 program represents the first opportunity for NASA to demonstrate the management "lessons learned" from the DC-XA program, as well as providing the platform for gaining extensive flight experience on a number of new technologies developed since the Shuttle. These include composite structures - including primary structure, diboride leading edges and nose cap - and advanced thermal protection systems (TPS). In addition, X-34 will also allow early evaluation of the operations cost of an economic reusable launch system, with direct feedback into X-33. The X-34 program is jointly-funded with the contractor, Orbital Sciences Corporation, with the Government's share capped at $70 million.

With the X-33, we undertake to demonstrate the technology required to achieve single-stage-to-orbit (SSTO). This program integrates and expands the achievements of the other efforts to produce an experimental vehicle which is both traceable at the subsystem level to a full scale SSTO and capable of demonstrating operations costs traceable to a high flight rate commercial SSTO.

Question 34: Are all three vehicle programs essential for the President to make a decision on a replacement for the Space Shuttle by the end of the decade?

Answer 34: All three programs are essential for government and industry to make a well-founded decision on a low-cost next-generation reusable launch vehicle. This decision, in turn, is pivotal for deciding around the year 2000 whether to transition from the Shuttle to a replacement next-generation system by 2012, or to continue to operate the Shuttle beyond 2012. Technical criteria are being identified that serve as the basis for deciding whether to proceed from one phase to the next.

Question 35: How will NASA continue forward with the RLV program given the cost constraints being imposed by the Administration?

Answer 35: NASA Administrator Daniel Goldin has stated that the RLV program is NASA's highest new-start priority. Through reprogramming, industry-shared support, and Congressional support for relatively modest increases for RLV funding, the requested levels of investment will be achieved.

Question 36: Will NASA evaluate the CANs differently, perhaps by giving the industry's proposed cost-share and business approach component greater weight in selection?

Answer 36: Each of the X-33 and X-34 CAN responses will be evaluated to the same standards. These evaluation criteria are listed in the two CANs.

Cost-share and business approach are both evaluation criteria. However, the government must be certain that the cost-share proposals are fungible by the proposer. Thus excessive cost-share proposals will be examined carefully as to the economic viability of the investment from the point of view of the proposer. If necessary, the government may require binding proof that the proposer is willing and able to fund their proposed cost-share.

Question 37: Would NASA consider dropping either of the RLV flight test demonstrators, the X-34 or X-33?

Answer 37: No, both are essential for a sound decision by Government and industry on next-generation launch systems.

Question 38: When will the DC-X be flown again?

Answer 38: Current projections are that the DC-X will complete its flight test program during the summer of 1995. This vehicle will then be modified with advanced component technology and flown again as the DC-XA.

Question 39: If DOD is responsible for expendable launch vehicles under this administration's space transportation policy, why is NASA proposing a new class of expendable launch vehicles known as Med-Lite?

Answer 39: The National Space Transportation Policy signed by the President on August 4, 1994, does identify "the DOD as the lead agency for improvement and evolution of the current expendable launch vehicle fleet, including appropriate technology development." However, the policy also states: "NASA will continue to be responsible for implementing changes necessary to meet its mission unique requirements." Consistent with the new Policy and the Launch Services Purchase Act, NASA continues to acquire launch services from the U.S. commercial ELV industry to support civil government payload launch requirements. The Med-Lite class of launch services NASA seeks is being developed by the U.S. commercial industry to meet commercial demand. NASA is simply taking advantage of industry's proposed new commercial launch services capability by baselining a series of new science missions, specifically Mars Surveyor, Discovery and MIDEX, to utilize this new class of service.

Question 40: How, if at all, is NASA coordinating its Med-Lite effort with DOD? Has DOD raised concerns or objections about NASA assuming the lead on this program? If so, have NASA and DOD resolved their differences?

Answer 40: NASA and the USAF have a variety of routine mechanisms in place through which ELV activities, including Med-Lite, are discussed and coordinated. NASA provides the USAF Space Command with an updated long range mission model on a monthly basis. The DOD National Mission Model reflected NASA's Med-Lite planning as of April 1993. In December 1993, NASA notified the USAF 30 Space Wing Chief of Plans of Med-Lite procurement planning. On July 17, 1994, NASA solicited USAF requirements for inclusion in the planned Med-Lite solicitation. NASA and the DOD conduct annual ELV Program reviews during which each agency discusses current and planned ELV launch activity. NASA provided status on each of the planned new services, Med-Lite and Ultra-Lite, at our July 19, 1994, meeting. The USAF Evolved ELV (EELV) Program Manager attended the Med-Lite Industry Symposium held on August 2, 1994. DOD did raise a concern in October 1994 with the perception of overlap between the Med-Lite solicitation and the emerging DOD EELV initiative. After clarification of each agency's plans, it was noted that the DOD EELV might extend into the

Med-Lite performance class; however, this version of EELV would not be operational until after 2002, and NASA has firm identifiable mission requirements beginning in 1998. NASA and DOD have since resolved the key difference for the foreseeable future, which was overlap between the two procurements.

Question 41: NASA's Mission to Planet Earth is a key component of the US Global Change Research Program. OTA believes that the program will not be able to provide decision makers with the information needed for making policy judgements--what do you think of OTA's position on this?

Answer 41: NASA disagrees with the OTA position on this issue. The design of Mission to Planet Earth and the U.S. Global Change Research Program (USGCRP) is based on the premise that the results of the research will be of significant value to government and other decision makers regarding the state of the environment. NASA is a science agency and we have aligned our research objectives and program implementation with the science priorities spelled out by the USGCRP. NASA's program addresses the most critical scientific uncertainties associated with the global environment, most notably trying to understand - and eventually predict -changes in the global climate. While we cannot predict what scientific conclusions we will reach - or specifically when - we have put in place an observation and analysis system which will enable us to build toward these conclusions in a timely and orderly fashion. We are confident that Mission to Planet Earth programs will lead to important discoveries and will form the basis for deliberations and action by government and business.

Question 42: What is the current life cycle cost of the EOS program--I'm especially interested in seeing what this program is estimated to cost after 2000?

Answer 42: NASA's Mission to Planet Earth is designed to provide a fundamental increase in our understanding of the Earth's environmental processes and to do so over a sufficient period to have confidence in this understanding. Our program has three primary elements, each of which can be characterized in a unique way from a life-cycle cost perspective. Flight projects traditionally have budget profiles which start slowly and peak about two years before launch. Mission operations and data processing activities depend on the number of spacecraft/instruments on orbit, the rate at which they return data, and the complexity of operations associated with controlling their activities. Scientific analysis and modelling is a fairly steady effort based on data received from satellites, aircraft, balloons, and ground research.

Attached is a summary of the costs currently estimated for Mission to Planet Earth, from 1991 through 2000. Beyond that time, cost estimates depend primarily on the strategy selected for developing and deploying spaceborne instruments, and to ~~a lesser~~ extent, derived activities associated with mission operations and data processing. Since we expect that substantial changes in program cost estimates will occur due to evolution in available technology (for spacecraft, instruments, and information systems), a fixed estimate of the costs beyond 2000 would not reflect the actual implementation of the program. Because EOS is the primary driver in a life-cycle cost estimate for MTPE, our methodology in examining such estimates might be helpful in thinking about the program over the long term.

1/23/95

Attachment 1

OFFICE OF MISSION TO PLANET EARTH
FY 1996 PRESIDENT'S BUDGET

(NOA IN RY $M)

ELEMENTS	PRIOR	FY 96	FY 97	FY 98	FY 99	FY 00	TOTAL THRU 00
EOS FLIGHT	**1607.3**	**591.1**	**639.0**	**753.9**	**737.8**	**807.0**	**5136.1**
AM SERIES	844 7	202 2	97 0	107 6	56 7	82 6	1390 8
PM SERIES	203 2	127.3	188 2	239 8	235 7	226 1	1220 3
CHEMISTRY	22 1	27 7	82 1	107 4	147 5	182 0	568 8
SPECIAL SPACECRAFT	146.4	69 7	92.9	95 8	89 1	93 0	586 9
(SAGE III INC IN SPECIAL)		(4.1)	(9 9)	(5 1)	(3 1)	(4 2)	(26 4)
EOS ALGORITHMS	196 9	85 4	122.7	154 5	200.8	221 7	982 0
LANDSAT	194.0	78 8	56.1	48.8	8 0	1 6	387 3
NEW TECHNOLOGY EARTH PROBES					**50.0**	**50.0**	**100.0**
EOS DIS	**663.2**	**289.8**	**309.8**	**291.9**	**317.4**	**358.7**	**2230.8**
EARTH PROBES	**512.3**	**36.9**	**28.0**	**11.8**	**7.0**	**4.8**	**600.8**
TRMM	202 3	24 5	21 6				248 4
TOMS	103.2	8 5	6 4	11 8	7 0	4 8	141 7
NSCAT	206.8	3 9					210 7
PAYLOAD AND INSTRUMENT DEVELOPMENT		**4.9**	**3.7**	**0.8**	**4.7**	**6.7**	**20.8**
APPLIED RESEARCH AND DATA ANALYSIS	**41.9**	**308.4**	**293.5**	**293.0**	**305.1**	**301.9**	**1543.8**
GLOBE	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**30.0**
CONSTRUCTION OF FACILITIES	**80.2**	**17.0**					**97.2**
LAUNCH SERVICES	**130.0**	**88.0**	**100.4**	**126.6**	**71.1**	**46.7**	**562.8**
SUBTOTAL OMTPE	**3039.9**	**1341.1**	**1379.4**	**1483.0**	**1498.1**	**1580.8**	**10322.3**
TRACKING AND DATA SUPPORT	**12.6**	**5.9**	**5.2**	**3.2**	**1.1**	**1.3**	**29.3**
TOTAL NASA	**3052.5**	**1347.0**	**1384.6**	**1486.2**	**1499.2**	**1582.1**	**10351.6**

NOTE

1) Funding for the ACTS Spacecraft and Upper Stage Are Not Assumed in the Above Numbers
2) Prior Year Funding in AR&DA only assumes the Ocean Color Data Purchase.
3) CofF Includes the Recission of CIESIN Funding.

For EOS, we are committed to a long term data set with instruments flown multiple times to enable us to discern the signature of climate change and to understand its processes. The baseline program involves the flight of 24 different instruments for at least 15 years of continuous set of EOS measurements for studying air, water, land and life from the unique vantage point of space. While we anticipate that the instruments and the spacecraft groupings would evolve over time, we must acquire the measurement "types" included in the program and do so continuously for 15 years. The accuracy and precision of these measurements must also meet baseline science and mission requirements.

NASA is initiating a study of how best to provide for the second and third flight of each measurement type. This study will carefully examine the improvements in technology applicable to both instruments and spacecraft, particularly possible reductions in size, power requirements, complexity, etc. We will also be looking at new and creative possibilities for domestic and international partnerships in the accomplishment of these objectives. This study will be done in concert with the scientific community to ensure that science requirements guide efforts to incorporate technologies, reduce costs, and adjust program schedules. We will also work with industry to better incorporate technological advancements expected over the next decade.

We believe that the implementation of the EOS program will occur in three distinct stages:

1991-2000 The initial work will be dominated by development costs for the instruments, spacecraft, and ground infrastructure needed to make the first series of EOS measurements (Enclosure). Since this first suite of EOS instruments and spacecraft are already well into the development phase, technological advances occurring today cannot be applied now, but will be fully utilized for the development of the second set of measurements beginning early in the next century.

With the expectation that these technological advances will reduce costs, we anticipate that EOS costs will peak shortly after the end of the century as development of the first series of EOS nears completion and work begins on the second series of less expensive, yet more advanced spacecraft and instruments.

2001-2012 This is an operational phase characterized by incorporation of technology advances in development of spacecraft and instrumentation, and likely expansion in interagency and international cooperation. Development costs will decline as new technology is brought on line. We are investigating the feasibility of operating in a cost capped environment during this period.

2013-2023 Our last instrument set is to be launched in 2013. After that, the budget for the program will diminish as development of spaceborne instruments and spacecraft ends, and the number of instruments on orbit begins to decline. This will lead to a steady decline in costs for operation of spacecraft and data analysis, followed by a brief period of final analysis of program data.

Question 43: How many EOS instruments are scheduled to be developed and do they all currently have confirmed flight opportunities?

Answer 43: Currently there are 24 different instrument types scheduled to be developed for EOS. All of the current instruments have confirmed flight opportunities except for the Active Cavity Radiometer (ACRIM) and the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) instruments. Currently we are pursuing small satellite flights for the ACRIM instrument and are negotiating with Canada for a cooperative mission for the SOLSTICE instrument.

Question 44: How many EOS instruments are dependent on international partners for their flights?

Answer 44: EOS funded instruments which are scheduled to fly on international spacecraft are CERES and LIS on TRMM (U.S. spacecraft launched by Japanese launch vehicle in 1997), SAGE III on a Russian METEOR spacecraft (1998), SeaWinds on the Japanese ADEOS-2 (1999), and possibly CERES on a follow-on TRMM mission in 2000, and SOLSTICE for which a definite launch opportunity has not yet been finalized.

Question 45. Which instruments have been dropped from the program since it began?

Answer 45: There were originally 30 different instrument types planned for the EOS A & B-Series. The present baseline for EOS is 24 different instrument types. The instrument types that have been dropped from the program since it began are:

INSTRUMENT		**REASON for DELETION**
ACRONYM	**NAME**	
ALT	Altimeter	Restructuring (1992); removed from the EOS B platform, reduced to one frequency and renamed SSALT for flight on EOS-ALT mission.
EOS SAR	EOS Synthetic Aperture Radar	Restructuring (1992); would have required funding outside the scope of EOS.
GGI	Global Positioning System (GPS) Geoscience Instrument	Restructuring (1992); replaced by the French instrument, DORIS, at no cost to the EOS Program for flight on the EOS ALT mission.
GLRS	Geoscience Laser Ranging System	Restructuring (1992); descoped and renamed GLAS for flight on the EOS ALT mission.

GOS	Geomagnetic Observing System	Restructuring (1992)
HIRIS	High-Resolution Imaging Spectrometer	Restructuring (1992); had been tentatively selected for A2 & A3.
IPEI	Ionospheric Plasma and Electrodynamics Instrument	Restructuring (1992)
LAWS	Laser Atmospheric Wind Sounder	Restructuring (1992); funding and technology issues.
MODIS-T	Moderate-Resolution Imaging Spectrometer-Tilt	Restructuring (1992)
SAFIRE	Spectroscopy of the Atmosphere Using Far Infrared Emission	Restructuring (1992); SAFIRE was overlapping the MLS science objectives. MLS was chosen for cost and science reasons.
SWIRLS	Wind Infrared Limb Sounder	Restructuring (1992)
XIE	X-Ray Imaging Experiment	Restructuring (1992)

Question 46: Will the data these instruments were to have gathered be obtained by other means? If so, how? If not, how will the data gaps impact the climate models that EOS data was suppose to help improve?

Answer 46: Three types of instruments have been deleted from the program:
(1) Particles and fields instruments
(2) Laser Atmospheric Wind Sounder (LAWS)
(3) High Spectral Resolution Imaging Spectrometer (HIRIS)/Synthetic Aperture Radar (SAR)

The particles and fields instruments would have studied the mesosphere and thermosphere. There are no plans to replace these instruments/observations as part of MTPE. While scientifically important to understanding the Earth's space environment, studies of these regions are not expected to contribute significantly to the development of accurate climate models.

The LAWS instrument was to provide tropospheric wind measurements for improvement of weather prediction skills and study of pollutant transport over continents. This will have some impact on the accuracy of climate models, particularly for evaluating events on a shorter time scale, and understanding air-sea interactions. Measurements of the type planned for LAWS would have been the first of their kind; no other accurate technique exists for measuring winds globally and regionally in the lower atmosphere. The main reason for deleting LAWS is lack of mature laser technology which would have dictated a very large and expensive instrument. Plans are underway to utilize the New Millennium Program for developing high power/yield solid-state lasers to demonstrate feasibility of this concept before considering flight as part of MTPE.

The focus of the HIRIS and the multi-parameter SAR instruments was the study of biosphere-atmosphere exchanges over land and oceans. Both of the instruments were dropped because of their size and complexity, and their power and resource requirements. Both would make an important contribution to understanding climate change, and NASA is pursuing alternative strategies for acquiring these observations. The Lewis spacecraft, one of the NASA small spacecraft technology initiative (SSTI) spacecraft, will carry a small high spectral resolution imaging spectrometer to provide space-based observation for the first time. Observations from the Lewis satellite will address certain EOS requirements in a technology demonstration mode. The Shuttle Imaging Radar (SIR-C) flights in 1994 acquired, for the first time, space-based multiparameter SAR observations that are now being analyzed by scientists. NASA also receives and processes data from European ERS-1 and Japan's JERS-1 radar satellites. NASA currently plans to receive and process data from the second European satellite, ERS-2, and the Canadian Radarsat, both planned for launch in 1995. Radarsat will make the first radar assessment of the Antarctic ice sheets, which supports important global change research objectives. The National Research Council's (NRC) Space Studies Board is conducting a study to assess the role that the U.S. should play in this area, given the on-going and planned activities by other nations.

Question 47: Does EOS still intend to gather 15 years of continuous data? If so, what additional risks to the data continuity requirement have been taken because of the spending cap through 2000?

Answer 47: EOS plans to collect, process and disseminate Earth observations over a period of at least 15 years. Some of the rapidly changing Earth system processes require continuous observations (i.e. atmospheric and surface temperature, atmospheric water vapor and humidity), while other processes (that change more slowly) will not require continuous observations. The risks associated with budget cuts primarily relate to designing and building 3-5 year instruments and expecting them to last 6 years (i.e. 6 years launch center for follow-on satellites in each series). Recent instrument performance indicates that estimated lifetime is often exceeded by actual lifetime.

Question 48: If EOS were to take another substantial budget hit, could small satellites, such as Climsat and Earth Probes, be used to enable the EOS program to still conduct a viable space-based Earth monitoring program?

Answer 48: We believe that, with current technology, the successive restructurings which reduced the cost of EOS by 60% have left EOS content vulnerable to near term budgetary reductions. Parts of the integrated information set would be at risk. However, future technology advances should bring down the cost of EOS over the long term. The technology which is on the horizon needs to be developed and demonstrated. We are examining alternative advanced technologies that may allow us to accomplish the EOS objectives with small instruments/satellites through the New Millennium Program in the first decade of the next century.

Question 49: Why will this spacecraft cost so much despite the significant reduction in its capability?

Answer 49: The apparent disparity in cost versus capability between the EOS A-1 and EOS AM-1 spacecraft can be explained by the following:

1. With few exceptions, the AM-1 bus subsystems are essentially as capable as the A-1 bus subsystems. Therefore, the costs through Critical Design Review (design costs) for these two spacecraft should be comparable. The planned cost for A-1 through CDR was $393 million. The actual cost for AM-1 through CDR was $325 million. The differences reflect relatively small savings due to reduced capability in some cases and simplifications developed by the GSFC Project. The GSFC Project estimates that the present AM-1 spacecraft is about 85% "as capable" as the planned A-1 spacecraft. The planned manufacturing costs for A-1 (including integration and test of the larger instrument set) were $334 million and for AM-1 are $236 million.

2. The instrument counts are misleading. In 1990, the A-series instrument grouping planned 15 separate instruments out of a list that included 18 or 19 instrument candidates. By 1991, we had identified 14 instruments for the A-1 spacecraft: AIRS, AMSU-A, MHS, ASTER, CERES, EOSP, HIRDLS, LIS, MIMR, MISR, MODIS-N, MODIS-T, MOPITT and STIKSCAT. If one allows 3 individual instruments for ASTER and 2 for CERES, we had a total of 17 instruments planned for A-1. For AM-1, the count using the same groundrules is 8. Thus, the ratio of instruments between A-1 and AM-1 is closer to (17/8=) 2:1 rather than (16/5=) 3:1.

3. ASTER is a major accommodations driver. For AM-1, 2 of the 3 of the AM-1 capillary-pumped thermal subsystems are for ASTER. Similarly, ASTER is a major driver for the onboard data storage capability, science data capture and downlink capability, and science pointing. In accommodating ASTER, AM-1 (an Atlas-class spacecraft) has retained most of the major performance requirements from A-1 (a Titan IV-class spacecraft).

4. Non-Recurring Expense (NRE) costs for A-1 and AM-1 should be comparable. Each spacecraft requires the same set of subsystems (power, thermal, structural, communications, etc.), contractor data items, breadboard/ brassboard developments, and so forth. We just held the Critical Design Review for AM-1. Costs through CDR -- primarily for design and other NRE -- are approximately $230 million.In summary, the government estimate for the cost of the A-1 spacecraft was higher than the contract cost. When we consider this along with the capabilities provided by AM-1 versus A-1, we find that the ratio of costs seems reasonable. We feel these points show that the expected cost for the AM-1 spacecraft is in line with the earlier planned cost for the A-1 spacecraft

Question 50: Are you able to employ prototyping as fully as you would like under the current funding profile for EOSDIS?

Answer 50: At present, NASA believes that its investment in prototyping for EOSDIS is consistent with the overall scope and funding level available for this system. These efforts are complemented by other agency programs such as those associated with the High Performance Computing and Communication

Initiative. Within the current funding level, both NASA managers and those managing contracts for the development of EOSDIS have the ability to increase spending on prototyping when warranted.

Question 51: Some concerns have been expressed in the scientific community that the EOSDIS design will not be responsive to the evolving needs of earth scientists -- is prototyping your answer to those concerns?

Answer 51: Prototyping in itself is not the complete answer. Prototyping is essential to the development of any evolutionary information system. It underpins an essential business of providing quality service to users on a continuing basis. Prototyping is critical in enabling EOSDIS to incorporate improvements in technology included in new marketplace offerings that seemlessly enable EOSDIS to be responsive to the changing needs of all users.

We have also implemented a number of other processes which address the concerns of users. Chief among these are the User Working Groups for the individual Distributed Active Archive Centers (DAAC) together with the EOSDIS Advisory Panel, which takes a system wide user perspective. Other processes include the interaction of scientific users with system developers allowing early examination of development prototypes, mock-ups, and pre-release versions of systems and their service components.

The current EOSDIS architecture is designed to enable user and technological change. This includes change needed to meet the needs of the scientific community as well as other current and potential users. NASA believes that the EOSDIS Advisory Panel is comfortable with the current system architecture, technology, and envisioned services. This was the stated result of the EOSDIS System Design Review last summer.

Question 52: What do you currently know about the potential size and makeup of the EOSDIS user community?

Answer 52: There have been several studies of this question for the research segment of the user community and efforts have been made to estimate this for other users of EOSDIS. At present, NASA is preparing for an EOSDIS Potential Users Conference to provide a more authoritative answer to this question.

EOSDIS represents a new type of capability which is intended to enable broad user community access to digital environmental information and thus what we know at present should be regarded as preliminary. In light of these uncertainties, EOSDIS is being designed to be evolvable and scaleable. System designs are tested to ensure that they can accommodate increases in system size and demand of at least a factor of five.

Question 53: Are available information system technologies sufficiently advanced today to support the unprecedented size and complexity of EOSDIS when it is completed? If not, is anything being done or planned within EOSDIS development to ensure that the needed technologies will be available?

Answer 53: We are confident existing and expected technologies are capable of supporting EOSDIS requirements. In addition to using technologies that exist today, the completed EOSDIS is designed to take full advantage of technological advances as they occur in the future through the use of just-in-time procurements, an open system architecture, prototyping, modular design, and other features.

Question 54: How many users is EOSDIS being built to support? Who are these users and what are their needs?

Answer 54: EOSDIS is not being built to serve a fixed number of users; it is being built to be able to expand in response to user demand (i.e. to be scaleable) and to be able to adapt to changing user needs (i.e. to be evolvable). At present, the prototype Version 0 of EOSDIS supports 5,000 distinct users with 35,000 to 40,000 accesses per month. To date, most users who have participated in working with the system developers and testing system capabilities have been drawn from the research community. Currently, the perceived user needs (not just those of the research community) could be summarized as:

1. Help in learning to use the system
2. Ability to determine quickly the general nature of the data holdings of the system
3. Ability to search the system for specific data by place, time, parameter (e.g. surface temperature), content (i.e. numerical values or words and phrases), and a variety of other parameters which are specific to individual data objects
4. Capability to browse and order data
5. Data delivery through both electronic means and physical media shipment
6. User help services including talking to a human being
7. Access to a wide variety of metadata (i.e. information about the data which is correlated with the specific data and describes their quality, how they were produced, references to the literature that explain the data and their use, etc.)
8. Direct access to system functions at various levels of the computer architecture to enable unneeded services to be bypassed and to enable efficient connection of user computers to EOSDIS for machine to machine interactions
9. Affordable, high band-width electronic network infrastructure outside of EOSDIS to enable ready access to all EOSDIS services 10. Indications that data and information are valid.This includes ties to the refereed research literature for use of data in scientific publications

Question 55: Is NASA designing the EOSDIS Core System (ECS) to primarily accommodate the stated needs of the several hundred principal investigators who have specific scientific experiments planned for the EOS program?

Answer 55:; No. The system is being designed to evolve over time to serve a broad range of users. The EOS investigators, however, have constituted the group within the research community most willing up to this point to participate in working with system developers in testing and evaluation. These investigators represent only a small portion of the research community who are expected to use the system. EOS investigators who are responsible for delivery and maintenance of algorithms and the intellectual quality control of the resulting standard data products have special interactions with EOSDIS which are not included as part of the services provided to users. These interactions are associated with the fulfillment of their contractual obligations as providers of data.

Question 56: What has NASA done to incorporate the diverse needs of the entire user community into development of the system?

Answer 56: Because of the nature of the system -- its evolutionary design and development -- it is safe to say that we have not yet incorporated all the needs of our diverse potential user community. The planned EOSDIS Potential Users Conference is a step in this direction. At present, other steps planned are broadening the Data Active Archiving Center (DAAC) user working groups to include more users from outside the research community, identifying representative non-research users to work with system developers in test and evaluation, and assigning an experienced NASA manager to work with any group who is considering extending EOSDIS to meet the needs of non-research users.

There are continuing efforts in these directions as well. First, NOAA and USGS have been involved in EOSDIS and both agencies serve a diverse community of users through their existing data centers including the Earth Resources Observation System (EROS) and National Snow and Ice Data Center (NSIDC) centers which are EOSDIS DAACs. The NASA Cooperative Agreement Notice (CAN) mechanism has been pioneered to select a set of proposals to use NASA remote sensing data in non-research activities and these will include many uses of EOSDIS by the diverse user population. EOSDIS is already operating and providing data to users without restriction (i.e. Version 0 is on-line); efforts are being made to determine the nature of the current user population beyond the aforementioned researchers.

Question 57: Do you agree that the true size of the expected user population, the frequency and duration of user sessions, and the resources available to users should be clearly defined before initiating development activities?

Answer 57: The design of EOSDIS has been the subject of extensive work with scientists and other users over the last eight years. This planning assumes a system of evolving capabilities meant to serve an increasingly diverse and expanded set of users. We feel confident that this process - and the basic premise for the architecture of the system - sufficiently defined the requirements needed to proceed with development of the system. Indeed, the prototype version of EOSDIS which is now on-line (Version 0) was meant to serve as a testbed for development of later iterations of the system. We have made use of creative development processes (including prototyping, incremental development, working groups, advisory panels, interagency coordination, and external research and review activities) to help us plan the design and development of the system and to help it evolve to serve user needs. Inherent in the EOSDIS design is the ability to take advantage of appropriate new technologies as they become available and adapting to changing user and service requirements without disrupting the quality of services required by current users.

In the final analysis, pursuing such an evolutionary approach means that definition of the exact size of the potential user community and its specific needs is not really necessary. System development must proceed along a path required to meet launch deadlines and to make data from existing missions available as soon as possible.

Question 58. The ECS contractor, Hughes, is currently spending $5 to 7 million per month on ECS. What specifically is Hughes doing with this money? Why is NASA investing so heavily in this new design before it is even known if it will satisfy the requirements of the scientific community?

Answer 58: Systems engineering, system design, development of evaluation packages, prototyping, assessment of available commercial hardware, software and vendor plans, participation in information industry standards groups and forums, user interactions, liaison to the DAACs, and administrative activities constitute the bulk of the work. Hughes spending is dominated by personnel costs but includes substantial support for prototyping of various system elements, especially those on the incremental development path resulting in the release of various evaluation packages (four such packages have been delivered to date). Before the end of this year there will be a substantial shift to the development of software and system deliveries and the procurement of hardware for Version 1 of the system begins next year.

The detailed system design includes the analysis of user and mission support requirements to progressive levels of detail, the translation of these requirements to detailed definition of functions and interfaces in the system architecture, and the mapping of architectural elements to commercial packages, identifying reusable functions from existing systems, and designing "glue" software to integrate them. Hughes has also developed the first four deliveries of the software tool kit to support the development and integration of the science algorithms.

NASA is investing in the ECS activity at the planned rate to meet the schedule of the EOS AM-1 and TRMM launches and to improve services to users at a planned pace with transition from Version 0 to Version 1 beginning in 1997. The science community has been well represented in the process that has led to the current architecture and preliminary designs for Version 1, and they believe these designs are innovative and evolutionary.

Question 59a: What are the life cycle costs (total costs) of EOSDIS? of EOS?

Answer 59a: NASA's Mission to Planet Earth is designed to provide a fundamental increase in our understanding of the Earth's environmental processes and to do so over a sufficient period to have confidence in this understanding. Our program has three primary elements, each of which can be characterized in a unique way from a life-cycle cost perspective. Flight projects traditionally have budget profiles which start slowly and peak about two years before launch. Mission operations and data processing activities depend on the number of spacecraft/instruments on orbit, the rate at which they return data, and the complexity of operations associated with controlling their activities. Scientific analysis and modelling is a fairly steady effort based on data received from satellites, aircraft, balloons, and ground research.

Attached is a summary of the costs currently estimated for Mission to Planet Earth, from 1991 through 2000. Beyond that time, cost estimates depend primarily on the strategy selected for developing and deploying spaceborne instruments, and to a lesser extent, derived activities associated with mission operations and data processing. Since we expect that substantial changes in program cost estimates will occur due to evolution in available technology (for spacecraft, instruments, and information systems), a fixed estimate of the costs beyond 2000 would not reflect the actual implementation of the program. Because EOS is the primary driver in a life-cycle cost estimate for MTPE, our methodology in examining such estimates might be helpful in thinking about the program over the long term.

For EOS, we are committed to a long term data set with instruments flown multiple times to enable us to discern the signature of climate change and to understand its processes. The baseline program involves the flight of 24 different instruments for at least 15 years of continuous set of EOS measurements for studying air, water, land and life from the unique vantage point of space. While we anticipate that the instruments and the spacecraft groupings would evolve over time, we must acquire the measurement "types" included in the program and do so continuously for 15 years. The accuracy and precision of these measurements must also meet baseline science and mission requirements.

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With the expectation that these technological advances will reduce costs, we anticipate that EOS costs will peak shortly after the end of the century as development of the first series of EOS nears completion and work begins on the second series of less expensive, yet more advanced spacecraft and instruments.

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Question 59b: What is NASA doing to incorporate the knowledge of the Intelligence Community into development of this complex data information system?

Answer 59b: NASA has been an active participant in the review of classified archives for possible application to environmental research. That review, conducted by the interagency Environmental Task Force, has been completed and recommendations are currently being considered by the Administration. NASA experts continue to participate in advisory and analysis activities related to carrying out the mandate to make environmentally relevant data gathered for national security purposes accessible to the global change research community. NASA is also a founding member, and a NASA employee serves as Executive Secretary for the Civil Requirements Group (CRG). This group brings together principal civil agencies doing environmental research (NASA, NOAA, NSF, EPA, DOE, USGS) for coordinated planning to ensure seamless transition of any declassified data which could have environmental applications. Over the last few months, CRG's primary focus has been on ensuring accessibility of declassified data through existing civil data and information systems (e.g., EOSDIS).

NASA has continued a program of active liaison with national security agencies on possible application of their technologies for use in unclassified research programs. Several individuals within the NASA team are working with the intelligence community to share knowledge relating to data and information systems. Several members of the intelligence community have participated and will continue to participate in Independent Annual Reviews of EOSDIS which NASA conducts to ensure outside objectivity in the management of its programs. NASA's contractors also have extensive experience with this community.

Question 60: What is NASA doing to review the need to support all 9 Distributed Active Archive Centers (DAACs)? Is every single DAAC essential to the success of the MTPE program? Will every DAAC process Earth science data?

Answer 60: NASA will be commissioning an external review of all DAACs to examine this question. Results are anticipated to be available by late summer. At present, all DAACs have roles and responsibilities which are believed to be important to the success of MTPE. The question to be answered is whether these functions could be more efficiently executed by fewer DAACs and/or in combination with other data centers without compromising the quality of user service.

At present, the Goddard, Langley, Marshall, Jet Propulsion Laboratory, Earth Resources Observation System Data Center (EDC), NSIDC, and Alaskan Synthetic Aperture Radar Facility (ASF). DAACs are processing Earth science data and will continue to do so. Oak Ridge is working within financial constraints resulting from last summer's EOS rebaselining to support selected field experiments. The needs of these experiments will determine the extent to which it will process data as opposed to archiving and distributing data. The Consortium for International Earth Science Information Network (CIESIN) is devoted to collecting and making available relevant social science data including economic and demographic data, which is needed in combination with natural science data to fully understand and assess global climate change. CIESIN will process and/or hold data only when necessary to meet user needs; whenever possible, CIESIN will provide access to data held and processed by others, putting this data into the context of EOSDIS and providing specialized user support for the use of non-CIESIN EOSDIS holdings as well as these other data and its own holdings.

Question 61: If you lose a spacecraft, how long will it take to launch a replacement?

Answer 61: How will data gaps that will last years affect the success of the program?

As noted earlier, the EOS program budget through 2000 has been cut by 60% since the program "new start" in 1990. In this constrained funding environment, it is simply not possible for us to spend limited program funds on backup spacecraft ("hot spares") that would be ready for launch in the event of a failure. We continue to examine alternate means by which we might be able to recover from the loss of an instrument or spacecraft on-orbit. Replacement of an entire spacecraft could take less than the 5-6 year interval for each spacecraft through reprogramming of existing funds to expedite construction of a replacement. This would require a careful trade study to determine the effects of such a funding shift on other aspects of the program.

In general, the loss of a spacecraft would mean a delay in the availability of science data products or a gap in our ability to produce such products. The effect of such a gap on the program would depend on its length and the extent to which related data could be secured by alternate means.

Question 62: What has been the total NASA funding appropriated, obligated and spent by CIESIN?

NASA HQ has issued two research grants for CIESIN and the funds spent through January 31, 1995 are:

		Value	Disbursed
Grant No. NAGW-2010	FY90/91	$12.9M	$12.9M
Grant No. NAGW-2901	FY92/93	$42.0M	$40.1M

NASA has awarded Contract No. NAS5-32632 with CIESIN. The planned funding for FY 1994 and FY 1995 is $10.8 million (includes the $5.0 million annually appropriated in FY 1994 and FY 1995, plus carryover funding from FY 1993). Through January 31, 1995, $3.6 million has been obligated and $1.7 million has been disbursed.

Facility funds were also obligated as follows:

Preliminary design	FY 91	$1.0M	Spent $1.0M through Jan 31, 1995
Final design	FY 92	$3.4M	Spent $2.1M through Jan 31, 1995

In FY 1993, $42 million was appropriated for construction of a headquarters building ($15 million was previously rescinded; the remaining $27 million has been proposed for rescission in the FY 1996 budget).

Question 63: Where does NASA stand in finalizing its contract with CIESIN to operate a SEDAC?

Answer 63: CIESIN has been developing and operating SEDAC under a letter contract with NASA since June 1994. A finalized contract is in the last stages of negotiation and will be completed by the end of March 1995.

Question 64: CIESIN previously was receiving grant funding from NASA--what tasks were being done by CIESIN for NASA that no longer will be performed under SEDAC contract?

Answer 64: All of the activities associated with CIESIN's FY 93 grant will be closed-out by June, 1995. The tasks were broken down by areas of the Work Breakdown Structure and include:

1.0 Data Acquisition and Data Development activities such as regional data collection and access efforts in China and Eastern Europe, as well as development of data themes for information searching called Thematic Guides.

2.0 Data Analysis and Information Technology tasks such as development of data visualization tools and tools to assist in searching large datasets.

3.0 Necessary SEDAC tasks, which will be transferred to the contract.

4.0 Science and education activities such as workshops, visiting scientist support, and classroom Earth projects.

5.0 Policy Data Studies such as coordinated policy assessments, policy needs studies, and policy requirements studies.

6.0 Management activities which were part of the overhead to oversee the above tasks.

Question 65: Do you foresee any future relationship between NASA and CIESIN other than the current SEDAC activity?

Answer 65: No. We believe that the current relationship adequately provides for NASA's needs in this area. Though we specialize in scientific research, NASA does not have the expertise in human dimensions necessary to enlarge this relationship. Beyond the current situation, NASA's long range plans do not include the development of an expertise in this area. However, we realize the importance of this component and we will work closely with the USGCRP to ensure that the appropriate agencies are fully engaged in this research.

Question 66: The previously appropriated funds--currently totaling over $27 million for a CIESIN facility will no longer be available if they are not obligated by this September 30th--is that correct?

Answer 66: Yes. Funds appropriated for Construction of Facilities projects are available for obligation for three years. As soon as an obligation is made, the funds are available until the project is complete. No funds for this project have been obligated so far, and the funds will lapse September 30, 1995 unless obligations are made.

Question 67: How does the CIESIN facility requirements compare to those of the other eight DAACs?

Answer 67: The CIESIN facility was never viewed solely as a DAAC. The facility was intended to support CIESIN's broader multi-agency funded activities which included research, software development, training, visiting scientists, as well as the usual DAAC activities. At many of the other DAAC sites these related activities had antecedent organizations, personnel and facilities in place. Many of these DAACs use existing facilities adapted to their needs.

SPACE SCIENCE

Question 68. Has Gravity Probe-B experienced any cost overruns that would cause it to come before the NASA Program Management Council (described last year to this Committee) for termination?

Answer 68: Gravity Probe-B (GP-B) has not experienced any cost overruns. Since GP-B was reorganized in October 1993, it has performed within cost and on schedule. Currently, GP-B is ahead of schedule by approximately 10 months.

Question 69. How does NASA intend to fit SIRTF, a $600 million initiative, into its sharply declining budget?

Answer 69: Funding requirements for ongoing developmental programs decline after FY 1996, allowing a wedge to form for the development of the Space Infrared Telescope Facility (SIRTF) with a planned launch in the FY 2001-2002 timeframe. This will be the last major project for astronomy in this decade.

NATIONAL AERONAUTICAL FACILITIES

Question 70: The Administration's FY 1996 budget does not contain matching funds for the construction of a new wind tunnel facility as stipulated in last year's appropriation. There is, however, a suggestion that the funding deadline be extended to September 1997. Do you expect to find the matching funds somewhere next year to apply to this program.

Answer 70: The Administration is requesting the extension in order to evaluate the program using the data gathered from the current study and obtain a firm cost-sharing commitment from the industry. At the point, the Administration will decide whether to seek substantial funding during the FY 1997 budget request process.

Question 71: This proposed wind tunnel facility, though vital to the health of our aerospace industry in the next century, is clearly in jeopardy due to its staggering cost projected at $2.5 to 3 billion. Now that the Administration has decided to defer further action until 1996, will a serious effort be made to develop alternative plans such as a signal transconic facility and upgrades to existing subsonic facilities in order to make this a less costly undertaking?

Answer 71: The National Wind Tunnel Complex (NWTC) is currently estimated to cost $2.28 billion, less industry and state contributions. Several options have already been evaluated during the course of the National Facilities Study. The NWTC team is currently sponsoring additional studies and is committed to finding the best solution to the nation's wind tunnel needs in the most cost-effective manner.

MISCELLANEOUS

Question 72: Are there systems, projects, or programs in NASA now that might be good privatization candidates?

Answer 72: NASA currently is undergoing a series of reviews in order to effect a major restructuring in light of budget realities. In the course of these reviews we are looking at how we conduct programs. In this constrained budget environment. NASA simply cannot afford to do things the private sector is better equipped to do. NASA must, and will, focus its resources on cutting edge research, technology, and science. We will keep the Subcommittee informed of progress in identifying areas which may lend themselves to greater private sector involvement or outright privatization.

Question 73. What will NASA s requirements for RTGs be both for the short-term and the long-term?

Answer 73: Requirements for Radioisotope Thermoelectric Generators (RTGs) for the Cassini program (3 RTGs and 157 Radioisotope Heating Units or RHUs) are addressed in the Fiscal Year 1996 budget request, consistent with the July 1991 DOE/NASA Memorandum of Understanding [MOU] between DOE and NASA Concerning Radioisotope Power Systems for Space Missions. Supplement No. 1 to that MOU delineates the specific responsibilities of the Department of Energy (DOE) and NASA relative to the provision of the RTGs and RHUs for the Cassini spacecraft.

NASA s space science mission model, and the corresponding future requirements for space nuclear power, are under review given NASA s plans to employ smaller spacecraft, where possible, to accomplish future space science missions. These plans apply both to outer planet missions and solar probe missions -- missions that tend to require RTGs, or other means of generating power.

Preliminary results indicate a continued requirement to maintain the infrastructure to support the use of space nuclear power. Additionally, it is anticipated that advanced development in space nuclear power will be required to support the move to smaller spacecraft. NASA and DOE are now in the process of identifying the proposed funding arrangements to support these future activities, and we anticipate that these discussions will be concluded in time to be reflected in the President s fiscal year 1997 budget request.

Question 74. What is the Administration s position on RTGs?

Answer 74: In general, NASA uses RTGs where they are the only feasible means of providing electrical power to a spacecraft, as with deep space missions where solar intensity is so low that with current solar/electric conversion technology, a spacecraft would require extremely large, heavy, complex solar panels. This alone makes the use of solar panels for such missions impractical. RTGs remain unmatched by any other power source for missions to the outer solar system or in regions of intense radiation, such as in close proximity to our Sun.

The Administration s position on RTGs and safety is that where they make sense, based on the scientific and technical requirements of the particular mission, radioisotope power sources (RTGs and/or RHUs) will be used. In all cases, RTGs will be designed to ensure that our missions are conducted consistent with interagency approval and with maximum attention to safety considerations.

PROGRAM MANAGEMENT COUNCIL

Questions 75-79: Last year, Mr. Goldin described NASA's Program Management Council to the Committee. This is a commendable procedure he initiated to review NASA programs that show a chance of running over their projected cost. What programs, if any, have come before the Program Management Council during the last year? What were the problems? How large were the program's cost overrun? What actions were taken? Were any programs terminated through this review process?

Answer 75-79: All programs with a development cost in excess of $200 million fall under the scrutiny of the Program Management Council (PMC). Independent reviews are performed at prescribed points in a program's lifetime and constitute the Agency's most rigorous independent assessment mechanism. Review teams, independent of the subject program, provide to the PMC the current outlook relative to original plans and expectations. This includes an evaluation of existing or potential technical, schedule or budget issues and proposed solutions relative to the allocated program resources.

The following programs had Independent Annual Reviews (IARs) conducted upon them and were reported to and reviewed by the PMC last year.

MISSION	PMC Rev. Date (1994)
High Speed Research Phase 2 (HSR2)	16-Feb
Tropical Rainfall Measuring Mission (TRMM)	22-Mar
Global Geo-space Science (GGS) (Wind Mission)	24-Mar
Collaborative Solar Terrestrial Research (COSTR)	22-Mar
Polar Orbital Operational Environmental Satellite (POES)	25-Mar
Relativity Mission--Gravity Probe-B (GP-B)	19-May
Earth Observing System - AM Spacecraft (EOS-AM1)	29-Mar
Earth Observing System Data Information System (EOSDIS)	29-Mar
Advanced Astrophysics X-ray Facility-Imager (AXAF-I)	12-Apr
NASA Scatterometer (NSCAT)	22-Mar
Second TDRSS Ground Terminal (STGT-WSGT Upgrade)	28-Jun
Mars Environmental Surveyor (MESUR)	25-Apr

Super Light Weight Tank (SLWT)	13-Jul
CASSINI - Saturn Mission	26-Jul
Hubble Space Telescope 2nd Servicing Mission HST-2nd MSN	28-Jun
Geostationary Operations Environmental Satellite (GOES)	13-Jul
High Performance Computing and Communications (HPCC)	14-Jun
Large Throat Main Combustion Chamber (LTMCC)	21-Jun
Alternate Turbo-Pump (ATP)	21-Jun
Multifunction Electronic Display System (MEDS)	28-Jun
Tracking and Data Relay Satellite F-7 (TDRS F-7)	19-May
MIR/Docking	14-Jun

In addition, the PMC received the results of new-start Non-Advocate Reviews (NARs) for the Advanced Subsonic Technology Program and the Earth Observing System (EOS) follow-on spacecraft, and a conducted special reviews of the Mars Observer failure, the Mars Global Surveyor Program, the EOS rebaselining and the Global Geospace Science (GGS) program restructuring.

All of the issues and problems presented to the PMC were manageable within the currently projected resources for the programs. All programs were operating within their allocated budgets, with the exception of GGS, which was waiting on the performance of the Wind satellite before continuing development of the Polar satellite. This delay did result in cost growth. No cancellation reviews were recommended as a result of cost growth and no programs were terminated. The trigger for a PMC cancellation review is a projected fifteen percent development or life-cycle cost overrun. None of the reviews actuated the trigger point.

The Agency plans to have independent reviews conducted and reported to the PMC for approximately 26 major programs in fiscal year 1995.

PROCUREMENT REFORM

Question 80: Has NASA been able to shift more risk onto its contractors by using more fixed price, rather that cost reimbursable contracts?

Answer 80: Yes. Over the last several years NASA Headquarters has been reemphasizing the need to choose the proper contract type and move toward fixed price contracts whenever appropriate. The contract award data over the last five fiscal years shows that the ratio of fixed price to cost reimbursement contracts is increasing.

Fiscal Year	Cost Contracts	Fixed Price Contracts	
1990	412	1412	(77.4%)
1991	375	1416	(79%)
1992	361	1615	(81.7%)
1993	303	1559	(83.7%)
1994	295	1579	(84.3%)

We believe that this trend demonstrates NASA's commitment to using fixed price contracts when feasible, and that the number of awards is the best measurement of progress in this area. The dollar value of awards by contract type is a far less meaningful measure since these numbers will fluctuate as a result of the particular requirements and programs initiated in a given year. (For example, a cost reimbursement arrangement is the proper contract vehicle for the $5.6 billion Space Station Freedom contract because of the many uncertainties in this technologically groundbreaking program, and the large value of this contract will skew the ratio of cost to fixed price award dollars in the year of award.)

This is not to say that NASA is awarding all its large dollar contracts on a cost reimbursement basis. We are subjecting our large dollar requirements to a rigorous contract type scrutiny and taking measures when applicable to ensure that these requirements can be satisfied on a fixed price contract. An excellent example is the recently awarded $481.6 million fixed price contract for three Tracking and Data Relay Satellites (TDRS). In using a fixed price vehicle for this program, NASA moved away from the traditional Government practice of developing detailed specifications that contractors were required to meet. Instead, NASA adopted commercial practices by identifying its requirements and allowing offerors flexibility in determining how best to meet those requirements.

Contract type is not the only means of shifting performance risk to contractors, and NASA is taking other measures to ensure the appropriate balancing of risk. For example, the TDRS contract referenced above requires the contractor to reimburse NASA in the event of a spacecraft failure. This commercial practice will save NASA money and ensure that taxpayers get the maximum value for their investment. This and other mechanisms will continue to be important contracting tools in building a more efficient and economical procurement system.

Question 81: What steps does NASA take to ensure that contractors bid realistically on contracts?

Answer 81: Cost is a factor in all NASA contract awards. First, for competitive negotiated awards (where award normally occurs only after discussions with offerors), cost is a mandatory consideration per the Federal Acquisition Regulation. In addition, NASA source selection regulations specifically require an assessment of the realism of the costs proposed by offerors and allow for downgrading an offeror's technical score if the proposed costs are considered unrealistic. Furthermore, our selection decisions are based on our assessment of what an offeror's approach will cost (the realistic cost) rather than blindly accepting the offeror's proposed costs. Second, for sole source awards, NASA conducts an in-depth analysis of contractor proposed costs, develops a negotiation objective based on that analysis, and then negotiates a realistic contract cost. Third, for sealed bid procurements (where award is made based on initial bids without any discussions with bidders), award is made on a fixed price basis to the responsive and responsible bidder that submits the lowest bid.

NASA takes cost realism very seriously. To ensure that we are addressing this issue as aggressively as possible, we are conducting a major reassessment of our source selection procedures to determine if even more efficient and effective measures are available to promote realistic cost proposals and evaluation of these proposals.

Question 82: NASA has acknowledged in the past that it has had difficulty managing contracts after award because of a shortage of procurement staff. What impact will NASA's downsizing have on its ability to oversee its contractors' technical and business performance?

Answer 82: The percentage of the annual NASA budget expended through contracts, grants, or cooperative agreements with the private sector is extremely high among federal agencies, approximately 88%. As a result, effective contract management is critical to accomplishment of the agency's mission, and it is, and will continue to be, a high priority agency objective. Because of our decreasing procurement staff, we have looked at different techniques to ensure that our contract oversight remains effective.

The most significant of these techniques is an increased emphasis on the accountability of program management personnel for contract management issues. This has had the effect of increasing the resources devoted to contract management even as the procurement staff level declines, while at the same time reinforcing the need for a team approach to manage our contracts. It is not possible at this time to predict the adjustments which may be necessary as a result of further downsizing, but we are committed to proper oversight of our contractors in any event.

Question 83: NASA has allowed contractors under cost reimbursable contracts to buy general purpose equipment instead of furnishing their own. What has been done to stop this wasteful practice?

Answer 83: In March, 1994, NASA amended its procurement regulations on providing equipment and facilities to contractors. In that revision, we note explicitly our commitment to reversing the practice of providing general purpose equipment and facilities to contractors. At the same time, the revised regulation recognized the significant investment already made in these items and provided a strategy to gradually reduce the equipment and facilities made available to contractors. The new policy permits existing items to continue to be furnished until the end of their useful life, at which time they are to be replaced, if still needed, by contractor-owned substitutes.

In addition, we have increased our oversight on compliance with the Federal Acquisition Regulation policy that contractors provide all required general purpose equipment and facilities to perform Government contracts. This oversight has taken several forms: Headquarters surveys of Center procurement operations, formal training courses, on-site visits to Centers by subject matter specialists, and improved interoffice communications at both Centers and Headquarters.

FINANCIAL MANAGEMENT

Question 84: When does NASA plan to implement, Agencywide, integrated financial record keeping practices that are consistent with generally accepted accounting principles?

Answer 84: We believe NASA's financial record keeping practices are consistent with generally accepted accounting principles. However, the NASA Inspector General is in the final stages of the annual audit of financial statements and while progress reviews indicate a clean opinion, we have not yet received the final report.

Through the years, NASA has employed an extensive financial management information system. It is based upon NASA's accounting principles, standards, and system design, approved by the Comptroller General in 1969. It has served the needs of the Agency, the Office of Management and Budget, the Department of the Treasury, and the General Accounting Office. This system provides budgetary information, employs standard account classifications, common definitions, internal controls, and consistent reporting formats. It provides data necessary to support the requirements of program and financial management functions within the NASA organization and is meeting NASA's internal and external reporting requirements.

While we believe the framework of the system is good, we are currently moving to explore the availability of off-the-shelf solutions that will meet the requirements identified in the Joint Financial Management Improvement Program Framework for Federal Financial Management Systems.

NASA has appointed a Project Director, who is currently in the process of devising a plan for proceeding with this endeavor to standardize business practices and processes related to financial management systems. In addition, the Agency is recruiting an Integrated Financial Management Systems Council, composed of senior managers, who will provide direction and guidance, as well as overseeing the progress of this new venture.

Every effort is being made to achieve this goal as quickly as possible.

Question 85: In compliance with the Federal Managers' Financial Integrity Act, when will NASA send to Congress the report detailing the high risk areas that OMB has identified within the agency and the material weaknesses that the agency has identified?

Answer 85: NASA submitted its annual Federal Managers' Financial Integrity Act Report to the President and Congress with copies to the Office of Management and Budget on December 2, 1994.

Response to written questions submitted by Cong. Rohrabacher resulting from the February 13, 1995, hearing.

Clementine & DOD-NASA Relationship

Two of the most exciting space projects in recent memory came out of the Ballistic Missile Defense Organization in the DOD. In the case of the SSRT/DC-X program, NASA created a relationship with the original DC-X team, leading to the DC-XA program. But this has apparently not happened with the Clementine team.

Question 1: The New York Times reported that Clementine's success was not well received by the Clinton Administration. Have any Administration officials said or written anything to any NASA employee to indicate any negative opinion of the Clementine mission, its team or any team member, or NASA's potential use of Clementine technology, facilities, or team members in achieving similar low-cost space science missions?

Answer 1: To the best of our knowledge, no Clinton Administration official has provided any negative feedback on the Clementine mission. In fact, the Administration has been supportive of NASA's efforts to incorporate Clementine's lessons learned throughout our space science missions.

Question 2: Was there resistance to using Clementine technology, facilities, or team members from within NASA, particularly in the Office of Space Science or at its Centers or contractors?

Answer 2: No. The Office of Space Science and NASA's Jet Propulsion Laboratory are taking full advantage of the generous sharing of lessons learned, technologies, and new ways of doing business that were part of the Clementine program.

NASA is taking full advantage of one of the most powerful technology transfer mechanisms, people. Colonel Pete Rustan (USAF) and Dr. Stewart Nozette, key players in the Clementine mission, are unselfish in their sharing of information about technologies, processes and experience. In addition, the Naval Research Laboratory's Paul Regeon serves on some of our independent Near Earth Asteroid Rendezvous (NEAR) and Mars Global Surveyor (MGS) flight program independent reviews.

NASA also studied Clementine operations very closely. Matched with our experience in the final months of Magellan (where we operated the spacecraft with significantly fewer operations staff than were used at earlier periods in the mission), NASA and JPL have already incorporated what we have learned from these missions into the operations design of our upcoming space science missions. It is in this area that we expect to see the most significant improvements as a direct result of the Clementine and Magellan missions.

Question 3: While it is clear that NASA has sought to learn from the Clementine mission, to what extent has NASA sought to incorporate specific Clementine technology, people, or facilities, into its space science program, rather than completely reinventing those capabilities and talent base within NASA?

Answer 3: In the Discovery Program's NEAR mission, being developed at the Applied Physics Laboratory/Johns Hopkins University, the spacecraft is using a derivative of the Clementine laser radar transmitter from the same industrial supplier. In fact, in the Discovery Program we are using some of the same Ballistic Missile Defense Organization (BMDO) management techniques and technologies, facilities, and people resources used in the DC-X program. NEAR has one Headquarters Program Manager and the Project Manager is the contractor, the Applied Physics Laboratory. As you will recall, the Applied Physics Laboratory was on the BMDO cutting edge of quicker, cheaper, faster missions with Delta 180, 181, 183, and JANUS. The same APL team, management techniques, and facilities are being used on NEAR.

The Mars Pathfinder project at JPL has benchmarked the Applied Physics Laboratory/Johns Hopkins University and the Naval Research Laboratory's approach and operations of Clementine. Benchmarking is a management technique that is central to Total Quality Management (TQM). These benchmarks are being used against Mars Pathfinder development and operations. The Mars Pathfinder had started development before the Clementine launch and demonstration of technologies, so the infusion of technology was mostly in the operations area.

Question 4: Do you approve of NASA participation in dual use missions such as Clementine, where technologies can be developed for both civil and military applications? Has any official in the Clinton Administration ever indicated either support or opposition to such missions to you or to your Staff?

Answer 4: We welcome partnerships for dual use missions. This is particularly true where planning is done at the beginning of a potential mission to ensure the proper development of substantive science mission objectives and requirements, as was the case when we worked with the Department of Defense last year regarding a proposed follow-on mission to Clementine. Unfortunately, the Deputy Secretary for Defense, John Deutsch, informed NASA that DOD priorities did not permit further partnership planning or implementation on this proposed mission.

Nevertheless, in his letter Mr. Deutsch also informed NASA that DOD remains interested in pursuing cooperative spaceflight opportunities that provide mutual benefit to both parties; NASA remains equally interested. We have taken action to ensure that the lines of communication between the NASA and DOD will remain open and future opportunities will continue to be explored. Should we jointly identify an appropriate dual use mission in the future, we will submit that information to the Committee as part of the President's annual budget request.

To the best of our knowledge, no Clinton Administration official has provided any negative feedback on dual use missions. The Administration has been supportive of NASA's and DOD's efforts to identify appropriate dual use missions that are mutually beneficial.

NASA's Transformation to Industry Technology Provider/Enabler

In your testimony on February 13th, you spoke of NASA no longer being an agency that industry would approach seeking development contracts, but rather a source of technology for their commercial application (in effect an NACA for space). Indeed, NASA's charter for 11 years has called for the "fullest possible commercial use of space", but this has not always been adhered to. Certainly the continuing cuts in NASA's out-year budgets indicates there will be less money for the old way of doing business, so there is pressure for privatization, etc..., but some interest are afraid of this change, and will pressure their elected representatives and NASA to delay further reform, probably leading to more pain and disruption over the long run.

Question 5: It's clear that the new NASA will have fewer employees and contractors. But in the past 14 years, corporate layoffs and downsizing has fed an explosion in the entrepreneurial business sector. What can the Congress do to accelerate the government's move toward purchasing goods and services from commercial space companies, in effect creating business opportunities for laid off NASA and contractor employees?

Answer 5: NASA is committed to taking advantage of existing commercial space service sources. An example is the agency purchase of domestic expendable launch vehicle (ELV) services for those missions that do not require the unique capabilities of the Space Shuttle. In these acquisitions, we take all measures possible to utilize and preserve the commercial nature of the ELV service marketplace by structuring our contracts for services only (no hardware purchases or development) and limiting NASA participation to minimal oversight activities.

We are also active in attempts to assist the development of new commercial space service sources through an aggressive technology transfer program and an increased use of cooperative agreements to promote the development and commercialization of new technology.

In addition, the recent changes made by the Federal Acquisition Streamlining Act of 1994 to broaden the definition of a commercial product and encourage its purchase will make it easier for NASA to increase its commercial purchases.

With these efforts underway, we currently do not have any recommendations for further procurement-related statutory assistance to increase commercialization. However, we will continue to assess the progress in this area and provide such recommendations when appropriate.

Question 6: Speaker Gingrich, Chairman Walker, and others have talked about the need for NASA to move beyond organizational reform to a more strategic transformation, which implicitly includes changes in NASA's program. Are these views in conflict, or do you feel that some specific NASA outputs can be cut back while increasing others, hence shifting NASA's program and improving net performance on the new program goals?

Answer 6: The transformation NASA is undergoing will profoundly change the way NASA does business. In the testimony to the Subcommittee on February 13, 1995, seven principles were emphasized that will guide the restructuring of NASA. These principles are:

1. Cut out duplication and overlaps and consolidate.
2. If we don't have to do it -- we won't.
3. Change the way we work with prime contractors.

4. Emphasize objective contracting.
5. Privatize and commercialize.
6. Work to change regulations.
7. Return NASA to an R&D agency.

We intend to use these principles to make the full $5 billion reduction to our outyear budgets. Over the last two years, NASA has achieved a 30% reduction in its outyear budget requirements through significant adjustments to NASA's programs and by trimming the structure of the NASA institution. To achieve this most recent reduction, NASA has chosen this difficult, yet necessary course of restructuring to preserve the future ability of NASA to continue its exciting programs. Only if the $5 billion in savings cannot be found through restructuring NASA will then turn to reducing funds for programs.

The dramatically different face of NASA in the future will have a real impact on NASA programs. The focus of NASA will return to cutting edge technology. There will be less oversight, less detailed direction, less involvement from government civil servants. The emphasis in NASA will be on R&D, not operations. This will be left to the private sector. The most important change to programs which will result from the transformation of NASA will be the emphasis on output of NASA's R&D activities. NASA will judge its success by the results of what we do, not by the level of dollars going in. This emphasis on program performance could very well shift resources for NASA activities. The shrinking pool of resources cannot support activities that do not deliver for the investment.

Question 7: The organic NASA Act was written during the Cold War to create a powerful agency that would do big projects in space for the country. Given the change from space-program executor to space-enterprise-enabler, isn't it time for a thorough revision of the NASA Act to empower and encourage NASA to move in the above-slated direction? Would NASA resist such an effort if initiated by Congress?

Answer 7: There is no need for a thorough revision to the Space Act. As written, the Act provides a great deal of flexibility and the authority granted in that Act is more than broad enough to permit NASA to serve a role as an enabler. There are. however, some roles and functions being suggested for NASA that could be seen to conflict with laws and policies outside the Space Act. A brief description of some areas in which legislative help may now be appropriate is contained in the Administrator's letter to Chairman Sensenbrenner of February 24, 1995, attached. We are not only willing, we are eager to work with Congress to discuss these and any other issues that exist relative to NASA's evolving mission, as well as to identify and modify any statutes which impede NASA's effort to achieve it.

Reusable Launch Vehicles & Launch Service Purchase

Both Chairman Walker and I have indicated that our support for NASA's RLV program is based on the goal of NASA helping industry achieve radical cost reduction in space access which makes possible a rapidly-growing commercial space economy in Earth orbit.

Question 8: There has been considerable public discussion in the space trade press that the RLV program's goal of a radical (i.e. an order of magnitude or

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

FEB 24 1995

The Honorable F. James Sensenbrenner, Jr.
Chairman
Subcommittee on Space and Aeronautics
Committee on Science
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

When we met on February 3, 1995, you asked me to identify statutes or regulations which impede our progress in changing the way we do business at NASA. Your interest in helping us achieve our goals in this way is truly appreciated.

In discussions with my staff, I have identified some areas in which near-term congressional modifications, requirements, or clarifications of intent could prove beneficial. Three such areas are discussed below. Before I mention them, however, I would like to stress that while NASA is, of course, required to comply with many rules, most of the real obstacles we face are internally generated. We cannot blame the system in which we and all other agencies work for the vast majority of the problems we face. I firmly believe that NASA can change the way it does business and become less bureaucratic and more flexible within our current legal framework. Some changes would help us meet our long-term goal of making Government more efficient and responsive, but we will be successful in our near-term efforts to revolutionize this Agency even without them.

In the forefront of our current effort to change NASA has been the move away from programs in which the Government specified all the requirements toward joint cooperative efforts in which Government and industry are partners. In these arrangements, cost sharing is a prime consideration. We have found that industry is often reluctant to invest its own funds when the Government's participation is not ensured over the life of that joint cooperation. To assist in this situation, either multiyear appropriations, covering the expected effort, or provision to NASA of limited authority to cover possible private losses, should the program be terminated prematurely by the Government, would be quite helpful. A mechanism to protect the taxpayers' investment, should the private sector be unable to meet its commitments, may also be in order. Beyond appropriated fund issues, statutory changes would also be helpful to clearly permit the use of independent research and development money in these agreements and to allow our cooperative partners to retain title to property acquired in performance of those agreements.

Another area in which we are concentrating our efforts for the future is in the transfer of NASA-developed technology to the private sector. Some of our most valuable technology is in the software we own, but since the Government cannot obtain a copyright on its software, we cannot control its distribution and use. The result is that industry is reluctant to invest in commercialization and improvement of our software. It would be a great aid to our commercialization efforts if we could protect our investment in software by obtaining a copyright and then licensing it to industry. A simple change to 17 U.S.C. § 105 would permit this.

The final area relates to a longer term problem than do the first two. Our approach to the development of the Reusable Launch Vehicle (RLV) is very different from the approach Government took for the development of earlier vehicles. While I am confident that we will be able to attract active participation in the X-33 and X-34 programs, I also know that we could face a problem when those programs succeed and it becomes time for industry to build the actual vehicles that will become the space transportation of the 21st century. The difficulties will not relate to the technology, they will relate to business issues. We are already hearing from some companies that concern over these matters will impact their corporate approach to the RLV program.

To help resolve this long term problem now and to ensure that our early work is correctly designed to maximize the probability that the vehicles will be built, it would be helpful for Congress to address these concerns and set some boundaries on the business arrangements that may be acceptable. Primary in this regard are issues related to the Government's ability to commit to use of the vehicle before it is built and to participate in coverage of termination liability should Government interest in the vehicle lapse. Other issues might arise concerning the applicability of trade agreements or facility, technical or other support the Government could agree to supply to the builder. In short, having a reasonable understanding of an acceptable business arrangement for the ultimate contract will go a long way toward assuring that the RLV program will succeed.

I realize that the areas discussed above are not fully developed. My staff is ready and willing to explain and expand upon them at your convenience. We are continuing to work to identify other issues and suggest additional areas of statutory or regulatory change. We will work with your staff during the weeks leading to markup to develop appropriate near-term statutory provisions and will continue to work with them as new ideas are developed. I want to reiterate my appreciation for your support and assistance in assuring that no unnecessary barriers stand between us and success in our efforts to revolutionize the Nation's civil space program. I look forward to working with you as are we streamline and strengthen our program.

Sincerely,

Daniel S Goldin

Daniel S. Goldin
Administrator

greater) cost reduction is too difficult, and that a factor of 2 or 3 is more achievable and sufficient. Do you agree? What level of cost reduction is your metric for RLV programs success?

Answer 8: NASA certainly agrees that cost reduction by a factor of 2 or 3 is easier than achieving an order of magnitude change in the price of space transportation. However, the Commercial Space Transportation Study (CSTS), conducted by industry with NASA sponsorship, concludes that reduction of the price of space launch below $1000 per pound is required before any significant new demand for space transportation will appear. In addition, recent suggestions of potential predatory pricing at the $1000-2000 per pound level by international space launch competitors further argues that reduction of the price of space transportation by an order of magnitude should be the goal to ensure the future competitiveness of the American space launch industry.

Step by step, we are working to achieve that goal. We estimate that a potential commercial spin-off of the X-34 might achieve a factor of 2 or more reduction in price compared to current systems in that payload class. The potential commercial spin-off of the X-33 demonstrator might offer a greater reduction in price (say a factor of 3 or more) due to the economy of scale associated with chemical rockets. Larger reductions appear achievable in an operationally efficient, full-scale RLV with a sufficiently large flight rate. We are simply too early in this developmental program to know for sure.

Question 9: I appreciate your commitment that X-33 and X-34 program funds will be fenced so that the X-34 cannot "take over" the X-33 funding stream, as some have proposed. Given that the X-33 is aimed at radical cost reduction and the X-34 is not, does it make sense to fund the X-34 at all?

Answer 9: The DC-XA and X-34 programs are the vehicles through which we will transfer into NASA the technology and--most importantly--the program management experience developed by the BMDO in the course of the DC-X program. While the DC-XA is a necessary tool for transferring that program management experience, it is the X-34 program which will establish that these new management practices are firmly embedded in the management of NASA's RLV program. In addition, the X-34 will offer early flight testing of a number of technologies developed subsequent to the Shuttle (including, potentially, composite structures, diboride leading edges and nose cap, and advanced TPS, among others). Finally, the X-34 is a necessary early opportunity to understand the operational costs of an RLV; these "lessons learned" will feed directly into the X-33 and any subsequent RLV programs, and are a critical component of the program.

Question 10: The X-34 program has alternately been advertised as a composite technology demonstrator and an operational system. Which is it? If the former, is it a necessary prerequisite to the X-33, or could ground-test data provide the same information more cheaply? If it is the latter, why is NASA developing an operational system, rather than buying commercial launch services as required by the Launch Service Purchase Act (Title II of the FY 1991 NASA Authorization)?

Answer 10: The X-34 program is to design, build, and fly an experimental vehicle. It is a jointly-funded effort with Orbital Sciences Corporation, with NASA's share capped at $70 million. The X-34 is intended to firmly establish small, fast paced, industry-led program management within the RLV program, as well as to flight test a number of technologies which have been developed subsequent to the development of the Space Shuttle but have not yet been flight qualified in a space launch system. The X-34 will also provide early ground operations systems experience on a reusable launch vehicle. It is likely that the X-34 (and, potentially, the X-33 as well) will be "spun-off" by our industry partner(s) into a commercial space launch system or systems. This potential subsequent development by our partner(s), using their own funding, is recognized by NASA as a necessary condition for industry cooperative funding of these programs. NASA funding for these programs will be directed solely at the development of the program management techniques, technologies, and operations methodologies necessary to meet our goals; no NASA funds are to be expended on development of any operational space launch system.

Question 11: The President's Space Transportation Policy calls for the Air Force to play an active supporting role in NASA's RLV program, particularly on the issue of operational cost reductions. But while Congress has appropriated funds to the DOD for this purpose, the Administration seems to have developed a pattern of impounding those funds until after the end of the relevant fiscal year. Doesn't the Air Force's Phillips Laboratory have an important and unique role to play in supporting NASA's RLV program, which is why you and your staff have actively sought their involvement? Wouldn't NASA's RLV program benefit from on-time funding of Phillips' supporting role? Might a cut-off of funding for the Phillips role have any deleterious effects on the NASA RLV program's schedule or results? Has anyone in the Executive Office of the President or the Department of Defense indicated to you why the Office of the Secretary of Defense has not accepted (or requested through budget action) appropriations for the Air Force's unique supporting role?

Answer 11: We expect the Phillips Laboratory to play an important role in managing the flight test of all three of our X-vehicles, and have included senior Air Force managers in the evaluation of the NASA Cooperative Agreement Notice (CAN) proposals as a necessary first step in developing a close working relationship with the Phillips Laboratory. Timely funding is an important part of any well managed program and is particularly important in a fast paced, small team effort where delays in funds availability can dramatically impact future program costs. NASA has worked closely with the Air Force in trying to resolve any budgetary issues which have occurred in the past and expects to continue to work closely with them in the event of any future problems.

Respnses to written questions submitted by Cong. Hall resulting from ghe February 13, 1995, hearing.

Question 1: For Code S and X, please provide for each Code the year-by-year funding through FY 2000 and the EAC for the New Millennium Spacecraft Program.

Answer 1: The OSS portion of the New Millennium program will start at $30 million in development funds per year for Fiscal Years (FY) 1996 and 1997, and will level off at $50 million per year starting in FY 1998. The expected funding levels, including launch services costs, are contained in the following table ($ in millions):

	FY95	FY 96	FY97	FY98	FY99	FY00	BTC	Total
OSS	10.5	30.0	30.0	50.0	50.0	50.0	cont.	
ELV's			3.0	10.0	17.0	17.0	cont.	

Note: The funding profile identified above includes the total level of support for New Millennium. Although the Offices of Space Access and Technology (OSAT) and Mission to Planet Earth (MTPE) are active participants, all mission unique funding is currently included within the OSS budget.

Question 2: Please provide the prior year, five-year funding profile through FY 2000, and EAC for each of the following programs:

Answer 2: The requested information is contained in the following table:

	FY95	FY96	FY97	FY98	FY99	FY00	BTC	Total
RLV	128.5	159.0	212.9	350.4	364.8	371.2	--	--
SOFIA		48.7	27.8	65.6	68.2	59.4	cont	269.7
SIRTF		15.0	25.0	75.3	85.3	120.2	312.7	633.5
FUSE		35.1	48.6	47.9	5.6	9.0	29.8	176.0
Discovery	173.7	145.4	118.1	160.7	198.7	194.8	cont	cont.
Mars Surveyor	72.6	8.5	89.5	98.6	104.2	107.3	cont	cont.

Note: SOFIA funding includes $30.3 million in FY 2000 for initial operation. Total development cost is $239.4 million, excluding cost savings achieved due to planned termination of the Kuiper Airborne Observatory in FY 1996.

Note: RLV FY 1995 funding includes $35 million from DOD.

Responses to written questions submitted by Congresswoman Seastrand resulting from the February 13, 1995, hearing.

Question 1: NASA's commitment to California is primarily, if not exclusively, for manned space functions. Please outline exactly how much NASA money is targeted for commercial space development in California.

Answer 1: On a geographical basis, NASA spends the largest percentage of its budget in the state of California. The major contractors which support the Human Space Flight program are located in California. However, the other NASA program offices spend a significant amount of NASA funding in California as well, which supports a wide variety of activities. There are two NASA field centers located in California, the Ames Research Center and the Dryden Flight Research Center. The primary focus at the Ames Research Center (ARC), located at Moffett Field, California, is to conduct fundamental aeronautics research, and ARC is the site of several unique wind tunnel test facilities. The ARC also supports research activities in Life Sciences, Physics and Astronomy and Space Access and Technology. The FY 1995 budget for ARC is $602.4 million; the major elements include: $234.8 million for Aeronautics programs; $63.5 million for Life and Microgravity Sciences activities; $169.0 million for the salaries and related support of ARC civil servants. The Dryden Flight Research Center, located at Edwards Air Force Base, California, is the primary site for conducting and supporting aeronautical flight testing. The FY 1995 budget for DFRC is $105 million; of that total, $48.9 million supports aeronautics activities and $38.8 million is for the salaries and support of DFRC civil servants. The Jet Propulsion Laboratory, located in Palo Alto, California, leads the Space Science program, and operates the Deep Space Tracking Network. The NASA budget for JPL in FY 1995 is approximately $1 billion. NASA spends approximately 80% of its funding on contract activities, and the majority of program funds spent in California are spent in the commercial market. NASA does not "target" funding for any geographical area.

Question 2: Please outline how much money -- state by state -- that NASA has allocated for commercial space development since you became Administrator.

Answer 2: There are two primary programs which focus on the participation of the commercial sector in space activities. The Commercial Technology program and Small Business Innovative Research (SBIR) programs are managed by the Office of Space Access and Technology. The awards made by these programs are based on the merit of the proposals vis a vis the technical requirements of the NASA programs. Funds are not allocated by state for these programs. In FY 1994/95, the SBIR program awarded 298 contracts, worth $84 million in the state of California. Within the Commercial Technology program, NASA directly supports the commercialization of its technology developed at Ames Research Center, Dryden Flight Research Center, and the Jet Propulsion Laboratory through its Commercial Technology Network. The budget for this network for these three centers is $6.2 million. This includes the funding for the Ames Technology Commercialization Center, which is dedicated to forming new California businesses based on NASA technology.

Question 3: Please break down the amount of NASA money that goes to California and the percentage of that money that supports manned-space functions.

Question 4: Please specify how much of the money which NASA sends to California that is syphoned out to Johnson Space Center in Texas and Marshall Space Flight Center in Alabama.

Question 5: How much of the money that NASA sends to California is targeted for manufacturing and how much for high-tech engineering and research?

Answers 3-5: These questions all request contract data. Although NASA collects various kinds of data on contract awards, our database does not segregate awards specifically by the requested categories of "manned-space functions," "manufacturing," and "high-tech engineering and research." However, we believe the following data for prime contract obligations in FY 1994 will satisfy the inquiries. Where feasible, this data is presented separately for the Jet Propulsion Laboratory (JPL).

a. Total amount of dollars for work actually performed in California (regardless of the primary address of the prime contractor):

$2,554,650,000	
1,093,382,000	(JPL)
$3,648,032,000	(Total)

b. Total amount of dollars awarded to companies whose primary address is located in California (regardless of the principal place of performance):

$2,792,964,000	
1,093,382,000	(JPL)
$3,886,346,000	(Total)

c. Total amount of dollars awarded to companies whose primary address is located in California and where the work is performed in Marshall Space Flight Center and Houston, Texas (we do not collect data specifically by Johnson Space Center):

$76,869,000	(Marshall Space Flight Center)
3,049,000	(Houston)
$79,918,000	(Total)

d. Total amount of dollars for work actually performed in California broken down by the categories of R&D, services, and supplies:

$1,298,223,000	(R&D)
517,286,000	(Services)
739,141,000	(Supplies)
$2,554,650,000	(Total)

e. The R&D category in item d. broken down by sub categories relating to different types of space activities:

$432,510,000	(Aeronautics and Space Technology)
210,414,000	(Space Science and Applications)
351,234,000	(Space Flight)
5,121,000	(Space Operations - Tracking & Data)
121,246,000	(Space Station)
4,196,000	(Commercial Programs)
156,488,000	(Other Space)
$1,281,209,000	(Subtotal)
17,014,000	(Other Non-Space R&D)
$1,298,223,000	(Total)

Please note that our retrievable data includes only prime contract awards. Subcontracts performed in California also represent significant expenditures of NASA funds. For example, although the prime contractor for the Space Station program is located outside of California, the recently negotiated contract for this program contemplates more than $2 billion of subcontract awards for work to be performed in California. These and other subcontract values are not included in the above figures.

Question 6. Please explain why NASA has been so adverse to commercial space funding in California and whether NASA has any plans of financially supporting any commercial space development in California.

Answer 6: All funding awarded for support of efforts to support commercial development of space is based on competitive, merit based review. NASA has a specific Commercial Development office at each Center, including the Ames Research Center and Dryden Flight Research Center, and the Jet Propulsion Laboratory, all located in California. The focus of these offices is to bring together companies in the private sector with technologies developed by NASA for the benefit of the commercial sector. The budget for the commercial development centers at Ames, Dryden and the Jet Propulsion Laboratory in FY 1995 is $6.2 million.

Question 7: In your statements and answers you emphasized that NASA was doing more for less and coming in under budget on selected big-ticket items. Please explain why NASA has continued to maintain a permanent presence with employees and contractors at Vandenberg when there are only one or two launches per year.

Answer 7: NASA's initiative to do more with less employs the strategy of using more commercial goods and services whenever comparable or better quality commercial capabilities are available at a lower price. NASA notes that the approach some state spaceports are taking to provide commercial services seems to result in a large disparity in costs for services. For example, Spaceport Florida's non-profit approach seems to result in significantly lower operations costs when compared to the California Spaceport's for-profit approach. NASA's future use of California Spaceport capability is strongly tied to lower user costs.

The NASA Resident Office at Vandenberg provides a wide range of functions, including serving as host to all civil government payloads in the 3-5 years prior to launch, coordination of NASA spacecraft requirements with the US Air Force range, maintenance of NASA facilities, and launch support. Currently 20 NASA-managed payloads are under development and funded for launch from Vandenberg over the next five fiscal years (1995-1999). An additional 5 payloads are planned, although not yet funded during this same timeframe. Hence, the NASA resident office supports an average of 4-5 launches annually in addition to daily support of payload/range safety requirements for missions planned for launch in subsequent years. The total value of spacecraft and launch assets requiring launch from Vandenberg over this time period is $3.8 billion and warrants oversight by a small multi-talented resident office.

Question 8: Please specify exactly how much NASA spends to support year round personnel and contractors at Vandenberg Air Force Base.

Answer 8: As a result of the recent buyout's the NASA resident office will be staffed as of March 31, 1995, at five civil servants for a cost of $325,000 and twenty-eight contractors at a cost of $2,500,000. The contractor, Space Mark Inc., is a small disadvantaged business who has performed well since selection in 1994. Each of the five civil servants performs multiple administrative and technical functions. The National Oceanographic Atmospheric Administration (NOAA) reimburses NASA for approximately 10% of the aforementioned civil service costs and 30% of the total contractor costs on an annual basis. Accordingly, maintenance of the resident capability provides civil government payloads comparatively low-cost payload processing, advanced spacecraft requirements range coordination and telemetry data from spacecraft pre-launch checkout through on-orbit spacecraft-launch vehicle separation.

Question 9. Regarding the Mission to Planet Earth program and the location of its headquarters across the country from its launch site, please list all headquarters functions in California in which launches are done elsewhere.

Answer 9: All headquarters functions for Mission to Planet Earth (MTPE) reside at NASA Headquarters in Washington, DC. Several MTPE launches occur at Vandenberg Air Force Base, since many of our spacecraft require polar orbits which can be achieved from the west coast. We also have east coast launches which fulfill other mission requirements. There are no headquarters MTPE functions in California.

Question 10. Would NASA have any interest in block granting money for the development of commercial space nationwide.

Answer 10: Awarding a system of block grants for the development of commercial space would be inappropriate. NASA awards its contracts on a competitive basis, on technical merit, compatibility with NASA's program needs, and after merit review. This method is incompatible with block grant programs.

Question 11: What is NASA's policy with regard to set-aside programs? Are there currently set-asides in place to achieve certain contracting goals? Is there a percentage involved? In allocating NASA money to various entities, such as JPL, do the existence of set-aside programs play a role in the determining of the level of funding?

Answer 11: NASA's policy on set-asides and utilization of specific categories of businesses directly implements various statutory requirements. The most significant of these requirements are the following:

a. The Federal Acquisition and Streamlining Act of 1994 (FASA) currently reserves all contracts between $2,500 and $50,000 exclusively for small businesses (the previous upper threshold was $25,000. Upon full implementation by NASA of electronic data interchange, the upper threshold will be raised to $100,000).

b. The Small Business Act (15 U.S.C. 644) establishes a government-wide requirement that 20% of all prime contract awards be made to small businesses.

c. FASA established a specific requirement for NASA that 5% of its total annual prime and subcontract dollars be awarded to small disadvantaged businesses (SDB's). (The previous requirement in two recent NASA Appropriation Acts established an 8% goal. However, the 8% goal, in addition to all SDB's plus Historically Black Colleges and Universities and Other Minority Institutions (HBCU's and OMI's), also includes all small woman-owned businesses.) In Fiscal year 1994, NASA awarded 9.9% of total contract dollars, including subcontracts, to SDB's, HBCU's and OMI's plus small woman-owned businesses.

d. FASA also established a similar 5% government-wide goal for woman-owned small businesses.

NASA has an aggressive program in place to comply with all these statutory requirements and is fully committed to fulfilling our obligations in this area. We meet our goals through several means. A primary tool is the small business set-aside program established in the Small Business Act. Our approach toward set-asides is consistent with the practice common among federal agencies whereby we first review our requirements to determine if they can be successfully performed by small businesses. If the result of this review is positive, we then restrict the competition for these requirements to such firms. Designation of an acquisition as a small business set-aside is determined by the specifics of the acquisition. NASA has no predetermined requirement for a specific number of set-asides in a given period, although we do have dollar goals established for these actions through agreement with the Small Business Administration (SBA) under the provisions of the Small Business Act.

Another method of making prime contract awards to a targeted business group is through the small disadvantaged business program established under section 8(a) of the Small Business Act. NASA determines whether this type of award is feasible through a process similar to the one described above for small business set-asides, in conjunction with consultations with SBA. (It should be noted that FASA authorizes the use of "set-asides" for small disadvantaged businesses also, if agencies need them to meet their statutory 5% goals. Prior to the passage of FASA only the Department of Defense had authority to set aside procurements for SDB's.

Apart from prime contract awards, NASA also uses subcontract awards in meeting its goals. Another statutory provision - the requirement for prime contractors to submit an acceptable subcontracting plan for contracts over $500,000, and over

$1 million for construction specifying the amount of subcontract dollars that will be awarded to small, small disadvantaged, and woman-owned businesses - provides a valuable mechanism to assist us in this regard. The subcontracting dollar amounts specified in these plans for each of the cited business categories vary from contract to contract and are a product of the subcontracting opportunities presented by the unique requirements of each contract.

In regard to the last portion of your question, set-aside decisions have no direct impact on the funding level of the JPL contract. JPL is subject to the subcontracting requirements identified above, however, and is contractually committed to awarding a specific percentage of its subcontract dollars to small, small disadvantaged, and woman-owned small businesses. under NASA's current 5 year contract with JPL, new subcontracting goals are negotiated each year. These are being successfully implemented under the direction of JPL's contractor capabilities office, with NASA oversight.

Responses to written questions submitted by Cong. Roemer resulting from the February 13, 1995, hearing.

QUESTION 1:

The Space Station continues to absorb a greater share of the shrinking NASA budget. Given the likelihood that this budget will continue to shrink, what new impacts will the space station budget have on the rest of our space program?

ANSWER 1:

The attached chart clearly illustrates that funding for the Human Space Flight and Mission Support appropriations continue to decline, while funding for the Science, Aeronautics and Technology appropriation continues to increase. This trend has been underway since the FY 1993 budget. When the NASA budget was restructured in the FY 1995 budget, the decision to fund Space Shuttle and Space Station activities in a separate appropriation was made to protect funding for the science, technology and aeronautics activities from any increase in the human space flight funding requirements. Thus, funding for the Space Station has been accommodated at the same time funding for Human Space Flight activities has been reduced.

NASA is in the process of fundamentally changing the way it does business. A series of reviews are underway which will lead to a much smaller NASA institution, thereby achieving the reductions included in the FY 1996 budget. NASA must, and will, focus its resources on cutting edge research, technology and science to enrich the lives of Americans and people all over the world.

QUESTION 2:

Last year, NASA testified that virtually every budget cut and savings had been identified and made. Yet this year NASA faces even $5 billion LESS than we thought about a year ago. How will NASA cope with the enormous cutback while leaving the space station sacrosanct?

ANSWER 2:

Beginning in FY 1993, NASA has reduced its five year budget projections by 30%. Every program has been affected by this reductions, including the Space Station. NASA is in the process of examining how it will achieve the outyear reductions included in the President's FY 1996 budget request through reductions in NASA's overall institution. A team is in the midst of conducting a zero-base workforce review to plan these reductions. Programs will be considered for reduction only if the needed reductions cannot be taken through restructuring. The dramatic changes needed to transform NASA into a more efficient, smaller organization will allow the agency to focus on cutting edge research, technology and science within a smaller budget envelope.

QUESTION 3:

What cuts will have to be made, now and for the rest of the decade, to meet the projected FY 2000 NASA budget?

ANSWER 3:

Achieving the outyear reductions included in the President's FY 1996 budget will require major reductions in the NASA institution. Between the FY 1993 and FY 1995 budgets, NASA achieved a 30% reduction in its five year funding requirements by restructuring the Space Station and major science projects such as Cassini, the Advanced X-Ray Astrophysics Facility and the Earth Observing System, and by reducing support contractors. To achieve the reduction included in the FY 1996 President's budget request, NASA is planning to restructure the NASA institution. Funding for NASA's programs will not be reduced unless reductions in the NASA institutions do not achieve the total required savings. NASA is at the forefront of the "reinvention" activities of the Administration, and is committed to becoming a smaller, more efficient agency. Change in the way NASA does business is already underway. Missions are smaller, cheaper to develop and to operate. The relationship between NASA and its contractors is changing. In the future, there will be less government direction, and much less direct government involvement in activities. This will allow NASA to focus on cutting edge research, technology and science within a smaller budget requirement.

QUESTION 4:

Is Space Science absorbing a disproportionate share of the required budgetary decline?

ANSWER 4:

The FY 1996 multiyear budget plan for NASA includes a reduction in total agency funding from the current level of approximately $14 billion to $13.2 billion by FY 2000. Within the NASA total, funding for Space Science is reduced as well, from $2.0 billion in FY 1995 to $1.5 billion. Nevertheless, the Space Science program will still be a world-class program of continuing discovery and exploration. The FY 1996 NASA budget request includes funding for several new initiatives. These include the New Millennium Spacecraft, the Stratospheric Observatory for Infrared Astronomy (SOFIA), planning and definition funds for the fourth great observatory, the Space Infrared Telescope Facility (SIRTF), and funds for future Discovery and Mars Surveyor missions. These new starts represent a necessary transition of the entire space science program to smaller, less costly missions that can still produce world-class science results.

QUESTION 5:

How will the new starts in the proposed budget effect important current projects, like Cassini and the Mars Surveyor.

ANSWER 5:

The proposed new starts in the Fiscal Year (FY) 1996 budget request will have no effect on current approved projects, like Cassini or Mars Surveyor. Both of these current missions continue to make significant progress toward their respective launch dates, and both are fully funded in the FY 1996 request.

QUESTION 6:

What is the floor below which the NASA budget should not fall?

ANSWER 6:

There is no floor for NASA's budget. Policy determinations by the President and Congress determine NASA's budgets. These policy determinations are made in the form of authorization acts and annual appropriation acts.

QUESTION 7:

What are NASA's main priorities given this budget climate? Are these what the priorities should be? Are these priorities being set by scientific considerations, or merely budget realities?

ANSWER 7:

The Administration's space and aeronautics policies assert the need for a balanced program across NASA's five strategic enterprises: Human Exploration and Development of Space; Space Science; Mission to Planet Earth; Aeronautics; and Space Technology. This program balance can be maintained with the level of funding requested by the President in the FY 1996 budget request. Within the FY 1996 budget request, the new initiatives included in the budget request - the New Millennium Spacecraft, and the Reusable Launch Vehicle technology development program - are high priorities. These programs are crucial investments for the future of this nation's space program, and are driven by both scientific considerations and budget realities. The results of these initiatives will result in a vibrant exploration program of both the space and Earth environment, allowing the launch of basketball-size satellites at a fraction of the cost required today.

QUESTION 8:

Administrator Goldin has called for fundamental restructuring. Given the reported enormous "management efficiencies" restructuring done last year, what does the Administrator mean? What will the function of the "new" NASA be?

ANSWER 8:

Since the FY 1993 budget, NASA has lowered its 5 year budget projection by 34% - a very impressive undertaking by any standard. In the FY 1993-1995 budgets, these savings were achieved through several actions. NASA's largest programs - the Space Station, Cassini mission, Advanced X-Ray Astrophysics Facility (AXAF), and the Earth Observing System (EOS) were dramatically restructured and the program costs reduced. Support contractor manpower levels have been reduced. Planned levels of spending for Construction of Facilities, administrative computer equipment, and institutional support were reduced. Civil Service personnel and related costs were reduced due to a very successful buyout in FY 1994. The NASA institution was marginally affected by these reductions, however fundamental changes were not made. The budget reduction in the FY 1996 budget requires a profound change in the NASA institution. Several teams are reviewing activities underway at NASA, and decisions concerning any restructuring at NASA will be made as part of the FY 1997 budget process. No decisions have been made about specific changes resulting from this restructure.

QUESTION 9:

Given the new Speaker's contention that it may be advisable to privatize the space agency, what are the prospects of such a move? Is it advisable and what would a private NASA look like? What would be its mission?

ANSWER 9:

The Speaker has indicated support for NASA's current restructuring efforts. In the course of the next several months NASA will be concluding a series of reviews and making decisions that will lead to fundamental changes in the way NASA conducts its mission. NASA's mission has always been, and continues to be to perform cutting edge research, technology and science to enrich the lives of Americans and people all over the world.

Responses to written questions submitted by Congresswoman Lee resulting from the February 13, 1995, hearing.

Question 1: Explain NASA's plans as to how they will address flat budget objectives. Also, if a Reduction-In-Force (RIF) is utilized explain the impacts to the minority workforce (Civil Service employees and Contractor employees). How does this affect NASA's diversity programs?

Answer 1: The multiyear budget plan for NASA reduces the budget from the current level of approximately $14 billion to $13.1 billion by FY 2000. NASA intends to achieve this reduction by "reinventing" itself into a smaller, more efficient organization. Since 1993, NASA has cut its five year budget plan by 30%, by restructuring programs, eliminating lower priority activities, and reducing support contractors. To achieve the most recent $5 billion reduction included in the five year plan supporting the FY 1996 budget, NASA intends to restructure the agency. The agency is currently conducting a top-to-bottom review of all of its activities to determine how to cut its workforce, facilities and contractor workforce. This transformation of NASA is being guided by the following principles:

1. Cut out duplication and overlaps and consolidate.
2. If we don't have to do it -- we won't.
3 Change the way we work with prime contractors - they'll do more, we'll do less.
4. Emphasize objective contracting.
5. Privatize and commercialize.
6. Work to change regulations.
7. Return NASA to an R&D agency.

The "reinvention" activities of NASA reflect the demand from the American taxpayer for a smaller, more efficient government. As a result of this process, NASA will evaluate results by the science, the R&D and the technical output of the dollars spent, not by the level of dollars going in. There will be less detailed oversight of contractors from NASA, both because there will be less civil servants, but also NASA will work with industry to define the requirements and then get out of the way. NASA will spend less on operations activities and more on cutting edge research and development activities. The current emphasis on smaller and cheaper science missions with shorter development times will result in a strong, vibrant research community. Although the total amount of NASA dollars will be smaller in FY 2000, the proportion of dollars supporting program activities should be higher.

A reduction in force generally has the greatest adverse impact on civil servants with the least amount of Federal service, especially non-veterans. Since many of our minorities and women fall into these categories, they tend to be disproportionately affected in a reduction in force. However, it is impossible to predict specific outcomes until a new structure is identified, and placement rights can be determined for those affected. Our diversity programs for hiring and advancing minorities and women remain an integral part of our operations. Because we do not have control over the downsizing processes utilized by contractors, we could not predict the adverse impact of their reduction on diversity.

Question 2: Provide distribution of employees slated to participate in the "buy-out" across the agency. Explain numbers per center if the agency did not fully benefit from the "buy-out" process.

Answer 2: Administrator Daniel Goldin recently announced his decision to make buyout available to any employee in the Agency who meets the legal requirements. There are no ceiling numbers at the Installations. We are determined to maximize the buyout opportunity while it remains available to us, to lessen the need for harsher downsizing measures in the future.

Question 3: Mr. Goldin indicated in the posture hearing on February 13, 1995, that Station was exempted from the cuts to assist with the anticipated $5 billion NASA funding shortfall. However, if the budgetary situation requires the Space Station program to take cuts, what are the impacts to the Program?

Answer 3: The Administration and the Congress have challenged federal agencies to streamline operations and improve the efficiency of federal programs. In response to this challenge, NASA has initiated a review process to identify options that will enable the agency to streamline, yet perform its vital functions within the available resources.

In 1993, the international Space Station program was redesigned to achieve world class science at a lower cost to the American taxpayers. Further, NASA also reduced the number of Space Station employees -- both civil servants and contractor support -- involved in management and integration by approximately 50 percent. The program was redesigned to meet the Administration's goals for the National Performance Review of better government at a lower cost to the taxpayer. This redesign resulted in a program commitment to a total cost funding profile and schedule in order to provide stability for the program to plan and execute. Additional cuts in the program would result in either schedule slips, which would add to the total cost, or loss of program content. Neither of these situations would be acceptable to the Station program or NASA management.

The Administration removed the Space Station from the outyear reductions based on this previous restructuring. However, the Space Station program continually looks for ways to improve its efficiency and we will continue to look for cost savings.

Question 4: It is my understanding that the amount of Extravehicular Activity (EVA) to assembly the U.S. portion of the Space Station would be 600 hours. What caused the increased EVA estimates and how confident are you with these hours.

Answer 4: Current EVA Scenario: The current estimate for U.S. Space Station assembly EVA is 648 crew-hours (420 by Shuttle crews and 228 by Station crews). We also have an estimate for Russian EVA of 240 crew-hours. That brings the total to 888 hours as reported in Space News' February 20-28 issue.

Last year, the program reported that 434 crew-hours of EVA would be required to build the Space Station; this is an increase to U.S. assembly EVA of 214 hours over the 4 1/2 year assembly period.

The scenario for maintenance EVA post-assembly complete has decreased from last year's estimate. In 1994, we told Congress the Station would require an average of 197 crew-hours per year for maintenance and the current estimate is 171. This saves us 26 hours of maintenance a year and 260 hours over 10 years.

EVA Is Not An Inherently Risky Tool For Assembly: Our experience demonstrates that EVA is a mature component of NASA's operations. No longer is EVA an inherently risky activity that is only used as a last resort.

Through our successes on-orbit and training procedures, we believe that EVA can be planned for, managed, and used as a valuable resource to build and operate the Space Station. We don't make this statement lightly -- we have the data to back it up.

The lessons of the Hubble Telescope repair mission show that complex EVA can be planned for and accomplished with the correct training and tools. These EVAs were difficult and time critical yet NASA completed them with relative ease. Furthermore, NASA is continuing that planning and training on the Space Station. With the Neutral Buoyancy Laboratory, we will be able to conduct additional, and higher fidelity, Station assembly and maintenance EVA procedures.

But we won't just do our practicing on Earth. We will also try out EVA assembly methods and tools in space during Phase I of the International Space Station. NASA is also demonstrating new suit technologies, so that our astronauts will be better protected, and a small, propulsion system (SAFER), so that they can get back to the Station if inadvertently separated.

Strategic mission planning to maintain adequate EVA margin -- extra time for assured mission success -- is perhaps the most critical element to the program's eventual EVA success. We are being very conservative in our planning so that neither mission success nor astronaut safety is impacted. The key element is that we build enough margin into our spacewalks to allow enough time for our EVA tasks and to account for any potential problems. This will be done at all stages of the design, development, and real time EVA execution.

Reasons For The Increase in EVA Hours:

Configuration Changes: To assure early U.S. power for scientific research, the program modified the assembly sequence. This caused the largest increase to EVA. There was also a significant increase to take Russia out of the critical path. Other EVA increases were mainly the result of a more mature design and the additional tasks for the centrifuge.

Cost: One of the key reasons for conducting an EVA is to conserve funding. Small increases in EVA time often result in large cost savings which are necessary given our current fiscal environment.

Space Station components that must be assembled on-orbit can be designed much cheaper if they are EVA compatible. Hand rails and simple mechanical fasteners are less expensive than robotic interfaces and specialized electromechanical devices required to accomplish the same tasks without EVA.

Weight Reductions: EVA also allows for weight reductions because the added weight of EVA materials - consumable gases, etc. - is usually less than the weight of hardware changes to perform a task without EVA.

Question 5: Is there duplication of space science programs across the Agency? If so, explain in detail?

Answer 5: There is no duplication of space science programs across the Agency. The nature of science is that we develop questions, design programs that will address those questions, review all the areas of science to determine the highest priorities across the program, and then select programs that will answer the highest priority questions. These programs are built and flown to collect the desired data, scientists analyze the data and build new theories based on what they have learned, and then they propose new questions. Then the cycle repeats.

Given this basic scientific approach, overlap is kept to an absolute minimum and in most cases is non-existent. Even when we design multiple missions to study the same area of the sky or the same celestial object, each mission has to have a compelling set of unique questions that it is designed to address. For example, we will send numerous missions to Mars, but each will be studying a unique aspect of the Red Planet. One will land and deploy a rover on the surface to study the Mars surface chemistry, while others will orbit Mars attempting to understand its geological past. In short, each will be designed to fill in another piece or pieces of the puzzle.

To ensure that this is the case, all space science investigations are peer reviewed or peer approved. Outside scientists who are knowledgeable of the proposed area of study review the proposed investigations for their respective scientific and technical merit, as well as their cost and management approach. Other selection criteria include technology transfer potential and planned educational or public outreach. All these factors are weighed, and the best proposals are selected. Proposed investigations that are duplicative do not generally survive this rigorous review process.

Further, it is the role of the Program Manager and Program Scientist assigned to each mission to eliminate any potential overlap among science investigations and activities. These government employees are responsible for the overall programmatic and scientific management of the mission. They are responsible for overseeing the expenditure of federal funds, and are empowered to manage their respective programs to ensure that the public's money is spent wisely and that the expected returns on the public investment are realized. This role has been expanded recently, especially in light of stringent cost caps for space science missions.

The Program Management Council (PMC) is empowered to review all major flight programs at the initiation of the project and on an annual basis against cost, schedule, and performance criteria. Projects that exceed their original cost estimate by 15 percent are automatically reviewed by the PMC for termination. This rigorous system helps ensure that unnecessary duplication and excess cost are eliminated.

Question 6: It is my understanding that NASA is moving from an operations environment to more of a research environment, will this affect the Shuttle and Station program and, if so, how? What is the impact to the field centers?

Answer 6: NASA has four reviews in place to aid in assessing agency operations and determining opportunities for streamlining, cost cutting, and operational efficiencies, without jeopardizing safety:

- The Shuttle Workforce Review, an internal review of Shuttle operations.
- An external, independent review of the Shuttle program headed by Christopher Kraft, former Director of the Johnson Space Center.
- The Zero-Base Review, a comprehensive study examining all NASA operations, including the civil servant workforce, contracts, facilities, and programs.
- The Federal Laboratory Review, which was initiated by the White House, and includes the participation by the Department of Defense and the Department of Energy.

The four studies are in various stages of completion and they shall all feed their results into the Zero-Base Review, which is due to Administrator Goldin on May 17. The Administrator is asking NASA employees to come up with creative ideas to meet an enormous budget challenge. NASA intends to move with speed, but also with caution and common sense to make revolutionary changes at the agency. How the agency will move from an operations environment to more of a research environment is not yet known, but the objective is to reduce civil service management of mature operational projects.

Question 7: What happens if industry fails with their involvement in the Reusable Launch Vehicles (RLV)? What is the "fall back" plan and what are the budgetary impacts?

Answer 7: If industry fails to develop, finance and operate the full-scale RLV system as currently envisioned. NASA and the Nation will face a major decision with regard to the future of U.S. civilian access to space, and in particular with regard to the Space Shuttle. The National Space Transportation Policy calls for NASA to maintain the Shuttle system until a replacement is available. A decision by industry not to commit to the full-scale RLV system could require NASA to embark on a substantial Shuttle upgrade program, including orbiter fleet augmentation, to maintain the safety and reliability of the Shuttle system while reducing its operating costs. While the budgetary impact is not known at this time, it could be substantial. This is why the RLV development program is NASA's highest priority "new start."

Question 8: Is there duplication of effort between Ames Research Center, Dryden Flight Research Center, Langley Research Center, and the Lewis Research Center? If so, explain in detail. Explain the impact of consolidating the research centers to facilitate budget objectives.

Answer 8: The Office of Aeronautics has consistently taken actions to eliminate overlap among the programmatic activities of its four Field Installations. In addition, the Office of Aeronautics has just completed a comprehensive roles and missions assessment of the four centers to ensure that future programmatic activities are undertaken only at the appropriate site. As part of this assessment, each Center has been named as a "Center of Excellence" in one or more critical research areas. In addition, each installation has been assigned specific roles within these Centers of Excellence to further define their programmatic responsibilities. These assignments are as follows:

Ames Research Center. Center of Excellence in Airspace System Operations, with lead roles in human factors research and air transportation management; and Center of Excellence in Information Systems, with lead roles in scientific computing, communications and networking, intelligent systems, and infrastructure technologies.

Dryden Flight Research Center. Center of Excellence in Flight Research, with lead roles in experimental aircraft, test bed research programs, and flight instrumentation and test technologies.

Langley Research Center. Center of Excellence in Airframe Systems, with lead roles in airborne systems, structures and materials, aerodynamics, mission and systems analysis, and crew station design and integration. Langley also has a lead role in hypersonic propulsion.

Lewis Research Center. Center of Excellence in Propulsion, with lead roles in subsonic and supersonic propulsion and propulsion support.

Based on this activity -- as well as on past actions -- the Office is confident that there is not, and will not be, any duplication of programmatic effort in Aeronautics.

NASA is currently facing some extremely difficult programmatic and institutional decisions as a result of continued downward budgetary pressures, and as a result of a perceived desire of the American public for a smaller, more effective Federal Government. In that environment, it is essential that we continue to support -- in the most cost-effective manner possible -- only the programs and facilities that are absolutely critical to the successful completion of our aeronautics mission.

As we strive to streamline and restructure NASA, therefore, we are examining every option for delivering quality products and services to our customers within our fiscal constraints. Some of these options include consolidating administrative and other support functions at a single location; closing lower-priority research and test facilities that have a minimal impact on higher-priority programmatic efforts; and increasing the financial contribution required from users of our facilities.

We are currently in the process of determining which of these options, and to what degree, to pursue. However, it is likely that independent of specific decisions, a restructured NASA aeronautics program will require less infrastructure, employ fewer civil servants and contractors, but will be able to address high-priority customer and national requirements.

Question 9: Is there redundancy of information data systems (administrative or programmatic) between the Shuttle and Station programs? If so explain in detail. Are there plans to integrate information data systems for Shuttle, Station and/or other programs?"

Answer 9: The Office of Space Flight (OSF), parent organization of the Space

Shuttle and Station programs, began identifying redundant information data systems some time ago. This effort began after realizing that costs associated with redundancy resided primarily in the hardware and its operating systems software. To correct this problem the OSF established the NASA Automated Data Processing Consolidation Center (NACC) in 1994 at the Marshall Space Flight Center, Huntsville, Alabama.

The NACC is designed to be a profit center and represents a new way of doing business. The NACC provides mainframe computer hardware and software platforms for both administrative and programmatic function supporting the Station and Shuttle programs. The OSF management has mandated that all OSF-sponsored mainframe systems be considered for migration to the NACC.

In addition, the OSF has efforts underway to consolidate and share "operational" computer resources for the Shuttle and Station programs. Both programs will use the same training facilities, simulation facilities and Mission Control Center in the future.

A "proof of concept" effort was accomplished to ascertain the scope of support to other NASA programs beyond the OSF. The NACC is now available for NASA-wide use by all NASA program offices and their administrative support functions. Potential candidate system are being evaluated for migration to the NACC.

Prior to moving a system to the NACC, however, a technical feasibility study and a cost/benefit analysis is performed to validate the migration.

Question 10: The metrics used to measure the effectiveness of the MTPE program focus on outputs. One group of metrics relates to the ability of MTPE to meet schedule and cost goals for the observation components of the program (e.g., launch schedules, field campaigns, etc.). These metrics are tracked on a weekly-to-monthly basis to ensure early detection of potential problems in performance. A second group of metrics involves the scientific output from the program, both at NASA Centers and at external organizations (universities, private companies, or Federal/State agencies). The publication of scientific results in the open scientific literature is tracked with progress reports submitted by each principal investigator. Special studies are also conducted to assess the impact of the NASA funded research relative to research conducted by other organizations using citation index information.

The MTPE program typically has more than 1600 funded science investigators in any year. These investigations are almost all selected through an external peer-review process. For example, in 1994 there were approximately 1100 scientists funded for research and analysis of existing data, and about 540 researchers working with instruments and data analysis methods for the Earth Observing System (EOS), or serving on interdisciplinary teams of scientists and engineers working on modeling and data analysis methods for using EOS data. These investigators represent 45 states, dozens of universities, colleges, and private research centers, as well as six NASA research centers and other government laboratories.

April 10, 1995

RESPONSES TO "QUESTIONS FOR THE RECORD"
HEARING MARCH 16, 1995
SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

By Jerry Grey, Director
Aerospace and Science Policy
American Institute of Aeronautics and Astronautics
Washington DC

Question from Hon. Ralph M. Hall: Some have argued that the aviation industry is a mature industry and thus the government has no appropriate role to play in cooperative research programs in high speed research or in advanced subsonic technology research. How would you respond?

Answer: There are two unique aspects to the aviation industry which do justify a role for the U.S. government in continuing to help reduce the technical risk of bringing new and improved products to the international marketplace. First, although the industry is mature in the sense that it has been established for some years, its economic viability and growth depend on the continuing introduction of new, extremely advanced, high-risk technologies which often take many years to mature. Ensuring global competitiveness in commercial aviation also requires the availability of large and costly facilities such as wind tunnels, which typically take years to build and are used by the government (for advancing its research base and for military aircraft development) and by most or all the commercial aircraft manufacturers, not just one company. Both these roles require long-term capital commitments far beyond the scope of any single manufacturer's balance sheet, and therefore have classically been filled by governments. Of course, once government-supported precompetitive R&D has reduced the technical risk sufficiently, the technology is transferred to industry and they then cover the cost of developing the new technologies and introducing them into their commercial products.

The second unique feature of the aviation industry is that this lucrative global and highly competitive market has attracted the strong support, both financial and political, of foreign governments who see in their own aviation industries a powerful source of national economic strength and employment. It is this government support which has enabled foreign aviation companies to usurp the formerly U.S.-dominated commercial markets for helicopters and commuter aircraft, both of which are now growing rapidly, and last year even to break the veritable market stranglehold once held by the largest U.S. manufacturer of jet transports. Congress may indeed decide to terminate U.S. budgetary support for high-speed research and advanced subsonic technologies, but the governments of our foreign competitors certainly will **not** stop supporting **their** aviation industries. The resulting loss to the U.S. taxpayers in taxable revenue, transportation cost and effectiveness, jobs, and balance of trade would far exceed the amount invested in NASA's aeronautics research.

Questions from Hon. Van Hilleary (see attached list for text of the questions)

Answers (numbers correspond to the attached list of questions; I have answered only those questions not specifically addressed to other panelists)

(1) Since 1949 aeronautical technologies have been advanced in the U.S. primarily by four entities: the National Advisory Committee for Aeronautics (and subsequently NASA, following enactment of the 1958 NASA Act); the Department of Defense, the U.S. aircraft/engine industry, and (for operational and regulatory aspects) the Federal Aviation Administration. Until relatively recently, technology advancement efforts by these entities were extremely successful in placing and keeping the U.S. as undisputed world leader in aviation. However, in recent years two factors have contributed to the significant erosion of that lead: (1) aggressive action by foreign aircraft/engine manufacturers, with strong financial and political support of their governments, in developing aeronautical technologies and test facilities that enabled them to produce highly competitive military aircraft, helicopters, commuter aircraft, and large jet transports, and (2) reduced emphasis by the Department of Defense on technology advancement having dual applications in civil aviation products, and reduction of NASA efforts in both basic and systems-oriented aeronautical R&D and test facilities.

(2) Construction of these seven wind tunnels was part of the aggressive action I mentioned in response to Question No. 1. They have helped the European manufacturers gain significant market share (indeed, Europe now dominates the global commercial market in helicopters and commuter aircraft). Moreover, U.S. manufacturers have been forced to use these tunnels, which are superior to existing U.S. facilities in many respects, to meet certain of their own test needs. With the recent entry of Russia into the global marketplace, AIAA expects the excellent Russian tunnels built since 1970 to help substantially in their industry's penetration of the civil aviation market and also to significantly enhance their already strong current market share of military aircraft sales to the other nations of the world.

(6) The longer the U.S. remains without high-Reynolds-number, low-cost, high-productivity test facilities, the greater will be the loss of U.S. market share, and the longer it will take to regain that lost share. Hence any delay in the analysis, design, development, and construction of the proposed National Wind Tunnel Complex will have long-term detrimental economic consequences to the U.S. taxpayers.

(7) The most important features of any projected site are those which affect its operating cost and productivity, because the proposed facilities will be in operation for decades. The key factors, therefore, are the guaranteed long-term availability of low-cost electric power, adequate water, and good transportation access for equipment, test articles, and personnel. Secondary factors which could help reduce the initial investment, and thereby the carrying costs of the facility, are the suitability of the site for construction and the availability of existing infrastructure such as power supply and conversion equipment, transportation linkages, instrumentation, shops and laboratories, etc. However, the potential reduction in carrying charges enabled by the use or modification (including modernization) of existing facilities must be traded off against any penalties such use or modification might impose on operational costs when compared with the construction and use of new, modern replacements optimized for the NWTC's specific needs.

(8) The U.S. government's principal roles in aeronautics are regulation, to ensure passenger safety and operational viability of the national air transportation system; provision and operation of the infrastructure needed to do so; the support of research and development of long-term, high-risk precompetitive technology and investment in national test facilities to help assure and maintain U.S. leadership in both civil and military aviation; and the promotion and support of equitable international trade agreements. Local governments also have an important role in regulating and supporting the construction and operation of airports and their access facilities. Note that these roles are not unique to aeronautics; government has assumed similar responsibilities in the automotive and other industries. Aeronautics is somewhat unique, however, because of the dominance of extremely advanced technology and the size and complexity of the facilities required to assure the economic strength of the aeronautics industry (see my answer to Congressman Hall's question).

(9) Because each agency has a specific and unique mission in meeting the aeronautics roles described above, it would not appear advisable to try to combine their often very different requirements into a single organizational structure. However, it is essential that the aeronautics activities and programs of the federal agencies be closely coordinated to ensure that there is no duplication and that important functions do not "slip through the cracks." It is important, too, that all institutions that represent the various elements of the national airspace system be included in the coordination mechanism.

(10) This question should be answered by the participants in the industry consortium which is conducting the current study.

(11) The NWTC will indeed confer long-term benefits in the cited areas, as noted in the AIAA's January 20, 1995 information paper "The New National Wind Tunnel Complex" which was provided to the Subcommittee with AIAA's testimony. The other agencies do support the NWTC effort, but because their roles are different from NASA's, their motivations for direct involvement in the specific technologies that will be advanced by the complex are not as strong as NASA's or the commercial aviation industry's. Therefore their support should be sought, but it should not be expected that such support will be nearly as comprehensive as NASA's or the industry's.

(12) The only alternatives to construction of the NWTC would be (a) not to construct it and continue to rely on foreign facilities; or (b) to attempt to obtain equivalent capability by modifying or upgrading existing U.S. facilities. The benefits and risks of these alternatives are examined in detail in the abovementioned AIAA information paper, "The New National Wind Tunnel Complex." The bottom line of our analysis is that (a) continued reliance on foreign facilities "would severely impact the ability of U.S. industry to compete on a timely basis," and (b) modifying existing U.S. facilities to meet the needs that would be satisfied by the NWTC would require almost complete rebuilding, and even then they would "not yield the unique combination of capability, productivity, and cost that the proposed NWTC is designed to provide."

(13) This question is similar to the one asked by Congressman Hall (see above for my answer to that question). The economic strength of the commercial aircraft manufacturing industry depends not only on the continuing introduction of new, extremely advanced, high-risk technologies, but also on large and costly facilities such as wind tunnels, which typically take years to build and are used by both the government and most or all of the U.S. commercial aircraft manufacturers, not just one company. Building such facilities requires long-term capital commitments far beyond the scope of any single manufacturer's balance sheet, and therefore they have classically been built by governments. The U.S. industry consortium has already agreed to provide 10% of the capital investment in the proposed NWTC, but has asserted that the majority of the required long-term, low rate-of-return investment should not and cannot be made by the private sector. In the competitive and lean international aerospace market, they say, U.S. industry simply cannot justify a $2.0 billion short-term cost to gain such very long-tern benefits. Also, the need to amortize the cost of the facility in a time period short enough to satisfy stockholders would inflate the price of U.S. aircraft, making them less competitive in the marketplace and defeating the whole

purpose of the new wind tunnels. Industry would, of course, pay the full operating costs of using the facility once it is built.

The contention that the commercial aircraft industry is the principal beneficiary of the NWTC does not recognize its broad implications to the global airspace system, U.S. economic stability, or the U.S. taxpayer. Aircraft improvements that will be achieved with the help of the NWTC address critical issues of airspace system capability, safety, and environment which benefit the general public. AIAA's testimony has highlighted the economic gains, in terms of direct and indirect jobs and tax returns, that would accrue from building the NWTC and from the improvement in market share it would generate. An important point, too, is that the lucrative global and highly competitive aircraft market has motivated foreign governments, who see in their own aviation industries a powerful source of national economic strength and employment, to invest the total cost -- and even support the operations -- of new, modern wind-tunnel facilities. These governments recognize the broad implications of low-cost, high-productivity wind tunnels to the overall improvement of their airspace systems and their national economies. In these countries, as in the U.S., the industry certainly does benefit from these installations, but so does their citizenry.

(14) As suggested in our testimony, the proposed NWTC represents an avenue by which the federal government could help the aerospace industry, as it has done in the past by building and operating the existing facilities, without providing a direct subsidy. However, because of the current focus on federal deficit reduction, mechanisms which allow that support off-budget should be considered. One approach AIAA has suggested is for the government to provide long-term, low-interest loan guarantees to an industry consortium which would build and operate the facility. The consortium would assume the economic risk, just as the contractors for NASA's new X-34 orbital launcher program have done. The loans would be repaid from user fees over a longer period than conventional commercial loans. The tax revenues cited in AIAA's testimony would provide an additional (although indirect) "payback" that would help compensate for the low interest rates.

One emphatic point the AIAA has stressed, as have both NASA and industry, is that funding for the wind tunnels must not come at the expense of the existing NASA aeronautics R&D programs: the aeronautics research and technology base, High-Speed Research, or Advanced Subsonic Technology. These programs are critical to the future success of the national aeronautics enterprise, to the traveling public, and to the U.S. economy. They cannot and must not be sacrificed to build the facilities.

Questions from Hon. Sheila Jackson Lee: All these questions were addressed to other panels, so I have not answered them here.

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON SPACE AND AERONAUTICS
U.S. House of Representatives
Washington, D.C. 20515

NASA: THE OUTSIDE OPINION

March 16, 1995, beginning at 8:00 a.m.
Room 2318 Rayburn House Office Building

HEARING WITNESS LIST

SECTION I: RESTRUCTURING

Mr. Rick Tumlinson
President
Space Frontier Foundation
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Mr. Wolfgang Demisch
Bankers Trust
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Mr. Gerald M. May
Assistant Director of the National Legislative Commission
The American Legion
Washington, D.C.

Mr. David Moore
Senior Analyst
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SECTION II: SPACE STATION/SPACE SHUTTLE

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Mr. Norm Parmet
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Aerospace Safety Advisory Panel
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SECTION III: REUSABLE LAUNCH VEHICLES

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For God and Country

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April 10, 1995

Honorable F. James Sensenbrenner, Chairman
House Science Subcommittee on
Space and Aeronautics
2320 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Sensenbrenner:

I have reviewed the transcript of my testimony before your subcommittee on March 16, 1995, and approve of it as written. In addition, the following is submitted in answer to the budgetary questions posed by staff, even though The American Legion's views are only tangentially related.

First, a flat budget could dramatically change NASA program execution and objectives. If such a budget were approved, I would expect to see programs slip, stretch or even be deferred to avoid spending. I would also expect to see funds reprogrammed where possible within NASA appropriated accounts in order to protect the objectives of the higher priority, more visible programs.

Second, flat funding and restructuring actions ought not to adversely affect already approved program funding milestones and safety, but invariably do in many ways. One impact is that restructuring and lower, constant budget baselines could force divestiture of certain task assignments or mission areas that have traditionally been a NASA responsibility. If such a restructure were unavoidable, the contractor and civil service work force could be retained to continue mission tasks transferred to other agencies with compatible interests. For example, transfer of major portions of the aeronautics research, developmental and procurement missions from NASA to the FAA.

Finally, I believe NASA is indeed, overemphasizing safety as it relates to restructuring. However, since much of what NASA does is extremely costly and manpower intensive, such safety considerations are warranted.

Thank you for the opportunity to testify on behalf of The American Legion.

Sincerely,

Gerald M. May, Asst. Director
National Legislative Commission

Questions submitted for the Record from the Congressional Budget Office

Questions from The Honorable F. James Sensenbrenner

QUESTION 1. What is--or is there--an appropriate relationship between NASA's infrastructure assets and facilities versus the programs that these facilities support?

ANSWER 1: The question cuts to the heart of the current changes going on within NASA. CBO's report *Reinventing NASA* (March 1994, pp. 19-34) presents a detailed discussion of issues involved in changing the way that NASA does business.

The long-term trend is toward less infrastructure, fewer federal employees, and more program as NASA shifts from owning and operating facilities and having in-house expertise to relying more on the private sector. In the early days of the space program, the expertise to accomplish the nation's objectives in space was unavailable in the private sector. After many years of activity and many dollars of federal spending, the capability to design, develop, produce, and operate space systems has spread from the public to the private sector.

In theory, NASA's workforce and facilities should be just large enough to maximize the benefits gained by the nation from the resources that are devoted to NASA's activities. The thorny problem with this formulation is that benefits are difficult to recognize and to value. For example, how important is a particular materials experiment in microgravity, and what is its worth? Or, are the contributions of NASA centers to local economic and social well-being to be viewed as costs of the program or secondary benefits? The traditional fallback in the face of difficult-to-value benefits is to agree on objectives and pursue them in as cost-effective a manner as possible. In that framework, the right mix of infrastructure, federal employees, and program is the one that achieves the agency's objectives at the lowest cost.

NASA has embarked on a search--program by program--to find the most cost-effective mix of infrastructure and program dollars to achieve agreed-upon objectives. The redesigned space station is a case in point. It seems likely that events will bear out the contention of NASA's management that the program was overburdened with NASA personnel. In this case, the direction of change is consistent with the long-term trend, encouraging those people who seek to shift the balance of NASA spending toward more program and less infrastructure. Yet even in the case of the space station, a large contingent of NASA employees, almost 1,300 full-time equivalents, remain after an aggressive review of the program.

QUESTION 2. Can NASA reduce employees while maintaining oversight of NASA contractors?

QUESTION 3. How much contractor program oversight can be provided by a shrinking civil service workforce?

ANSWERS 2 & 3: Much of the answer to question 1 applies to these questions as well. If NASA is to be successful and alter the mix of its spending to favor programs rather than infrastructure and employees, fewer NASA employees will be involved in the oversight of its contractors.

Traditionally, NASA has maintained oversight of its contractors by close "hands-on" supervision. That type of oversight--referred to as contractor penetration--required NASA personnel to be on-site, literally looking over the contractor's shoulder, as launch vehicles and spacecraft were produced. The growing competence of the private sector in producing launch vehicles and spacecraft has reduced the need for this type of oversight in some of NASA's activities. The alternative is to shift more responsibility to the private-sector contractor by purchasing finished systems, services, and data. Using that approach, NASA would specify the capability or information that it would like to buy, rather than the details of the hardware that would be necessary to produce those outputs. Where practical--for example, in space communications--services would be purchased on a firm-fixed-price basis rather than on a cost-plus basis.

As previously indicated, NASA is in the process of reviewing its major programs with the objective of doing more for less. CBO's report *Reinventing NASA* (March 1994) reviewed that effort and found that although improvements in management--including the oversight of contractors--were possible, they would take several years of sustained effort to achieve.

QUESTION 4. What are the risks associated with reducing program oversight?

ANSWER 4. Poor performance in the form of cost overruns, late delivery, subpar system capabilities, and visible mission failures are the risks associated with reduced program oversight.

Question from The Honorable Ralph M. Hall

QUESTION. In a January 24, 1995, meeting with staff, NASA's Associate Administrator for Space Access and Technology stated that NASA's implementation plan for its part of the National Space Transportation Policy was based on the Fiscal Year 1995 budgetary runout for NASA. In view of the outyear cuts contained in the FY 1996 NASA budget request, are the assumptions contained in the implementation plan still valid, or should NASA consider restructuring the proposed Reusable Launch Vehicle program to reflect the revised funding outlook?

ANSWER. The Administration has requested roughly $4.5 billion less for NASA over the next five years than was implied by the plan accompanying the President's 1995 budget request for the agency. Nevertheless, the President's 1996 request for

NASA calls for $68.4 billion in funding for 1996 through 2000. The Reusable Launch Vehicle (RLV) program is projected to require $1.45 billion over the same period, just over 2 percent of that total.

CBO cannot say what NASA should do to reduce its program to fit within the confines of a smaller budget. On the one hand, the small size of the RLV program compared with NASA's total budget suggests that if the agency were to make the program a priority, the reductions necessary to stay within the agency's lower overall level of funding could be made elsewhere in its program with little disruptive effect to NASA's overall plan. On the other hand, to the extent that the list of untouchable programs grows large, those activities in which reductions are made will suffer disproportionately. Ultimately, such reductions will change the character of NASA's program, perhaps in the direction of one of the three generic options included in CBO's testimony.

Questions from The Honorable Sheila Jackson Lee

QUESTION 1. If Congress proposed a Flat Budget for NASA, explain the impacts that you would expect from NASA as it relate to programs, reduction in force, impact to schedule, safety, etc.

ANSWER 1. Since 1991, NASA's budget has been essentially flat. As a consequence, many of its programs have been canceled, diminished, or delayed. Although formal reductions in force have not been necessary, normal attrition and incentives offered to encourage early retirement have reduced the agency's full-time-equivalent workyears--a measure of federal employment--from 26,700 in 1993 to just above 23,000 in 1995.

As CBO testified, the President's request for 1996 would accentuate the recent trend and, if approved by the Congress, further decrease the real resources devoted to NASA. Reduced funding will require additional cuts in programs, the federal workforce, or support for NASA facilities.

At this time, CBO cannot assess the effect of budget reductions on the safety of NASA's activities.

QUESTION 2. Is it feasible for NASA to consider restructuring without taking large cuts in the civil service and contractor workforce in order to meet budget objectives?

ANSWER 2. Reductions in NASA's budget will lead to reductions in the civil service or contractor workforce, whether the agency chooses to restructure or not. The Administration and NASA's management have indicated that restructuring will include a reduction in NASA's complement of federal workers so that program dollars--many of which pay the contractor workforce--can be maintained.

Although other approaches to restructuring could be imagined, a consensus among observers of the space program inside and outside of government is that reductions in NASA's federal workforce are a necessary part of restructuring the agency to allow it to function within tighter-than-anticipated budgets.

QUESTION 3. Do you feel that NASA can restructure the agency without impacting safety practices that were put in place after the Challenger accident?

QUESTION 4. Do you feel that NASA is over emphasizing the safety as it relates to restructuring?

ANSWERS 3 & 4. At this time, CBO cannot assess the effect of budget reductions or restructuring plans on the safety of NASA's activities.

Questions submitted for the Record from Mr. Parmet

QUESTIONS SUBMITTED BY
THE HONORABLE F. JAMES SENSENBRENNER, JR.

Question 1.

In your testimony, you state that though the annual number of flights has been reduced to seven, the importance of the joint US and Russian missions and the Space Station assembly does not necessarily reduce pressures on the schedule. Would you say then that the proposed flight schedule is - in terms of the complexity of the missions - a "compressed" schedule, and therefore very ambitious?

Answer 1.

The decision to limit the number of flights of the Space Shuttle to seven is based primarily on available resources. In a perfect world the Space Shuttle program would spread these flights evenly over the year and plan the use of available Shuttle assets and resources accordingly. Unfortunately, we not live in a perfect world. Unique mission requirements, weather delays, spares and logistical problems and other unknown or unanticipated issues can lead to loss of contingency days in processing schedules which in turn will lead to the necessity of grouping launches back-to-back. This is why I believe the reduction in the number of annual flights to seven will not necessarily reduce the pressures on the schedule. In addition, the fact that the joint US and Russian missions and Space Station assembly will be under constant scrutiny from the public, press and Congress can only add to the feeling of urgency . I would not classify the schedule as being "compressed" but rather "less flexible". When the NASA budget is reduced by more than $5 billion over the next five years, something must give. In this case, it is the ability to respond as quickly as before to unforeseen events. The overall schedule is very challenging when you take into account the total number of flights required for complete assembly of the Space Station, and then add in other Shuttle missions in this time period plus factor in the scheduling complexities introduced by the inclusion of the Russians and International Partners.

Question 2.

You have referred to the increased work force requirements which were mandated by the Rogers Commission recommendations following the Challenger accident. Now that we know the origin of the increased requirements, can you tell us how reductions have been planned? In other words, are the reductions in the Shuttle work force based on future requirements, or are they based on historical data?

Answer 2.

Reductions in the Shuttle work force that have thus far taken place have been as the result of careful review and study by the Space Shuttle program office. These studies in general assumed that reduced resources would be available and that efficiencies would have to be found either in

QUESTIONS SUBMITTED BY
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(continued)

processing techniques or the transfer of functions to other organizational units. The question is not whether the work force can be reduced further but rather how much and how those reductions will be implemented. Many of the mandatory inspections and oversight requirements that were put in place as a result of the recommendations in the Rogers Report are being reviewed and eliminated. For instance, the expanded use of Structured Surveillance techniques is allowing the government inspectors to survey and audit the process rather than having to do detailed inspection of every step. The Safety, Reliability and Quality Assurance organization at Kennedy Space Center has undertaken an effort to combine many of the existing requirements and mandatory inspections into a simplified set of principles and specifications and thereby eliminating unnecessary duplication and inspections wherever possible. This is all being done in a carefully controlled process in order not to impact safety. The danger in further reductions in the work force is that there will be a rush toward implementation in the name of efficiency or "re-invention" without the analysis required to assess the impacts on safety. Obviously not everything that may be cut during further reductions will have safety impacts but there is sometimes a tendency to assume that safety just "happens". It is far better to approach additional reductions very carefully than to find out after the fact that you have cut too deeply in the area of safety.

Question 3.

In its 1994 Annual Report, the Aerospace Safety Advisory Panel raised a caution about continued reductions in funding for Shuttle operations. NASA recently announced that its Work Force Review had identified efficiencies which could result in trimming another 6,000 people from the Shuttle work force. Has the ASAP had an opportunity to review these findings, and if so, what was the panel's assessment of the reduction on Shuttle safety?

Answer 3.

The ASAP has not had the opportunity to review the plans in detail but will be given an in-depth briefing on the subject within the next month. The Panel has always taken the position that safety must remain paramount and cannot be allowed to be impacted by reductions in the work force. Any reductions in the work force must take into account the fact that NASA has the responsibility to protect a national asset ---the Space Shuttle and its crew. No matter what single-contractor operational structure or privatization scheme may be proposed in the future, the space program and its assets

QUESTIONS SUBMITTED BY
THE HONORABLE F. JAMES SENSENBRENNER, JR.
(continued)

belong to the people of the United States and must be safeguarded accordingly. Any reductions in safety must be made in the areas of duplication and unnecessary oversight and not based on percentages or cost-benefit analyses. There may be areas other than the direct work force that can be effectively reduced without affecting direct operations. For instance, it is possible to change the design engineering function over to a sustaining engineering function and thereby limit the number and type of engineering changes allowed.

Question 4.

Has the ASAP had an opportunity to review NASA's plan to enhance Shuttle performance for the space station program? In the enhancement program, NASA is making a number of changes which, at some point, must be integrated. Has ASAP assessed NASA's systems integration efforts for the enhancements? If so, what were the results of the assessment?

Answer 4.

The ASAP regularly reviews and monitors many of the Space Shuttle enhancements being proposed to increase the lift capability needed to support the Space Station. In particular, the Panel is following closely the Space Shuttle Main Engine (SSME) enhancements and the new Super Light Weight External Tank. We believe both these changes are needed to help meet the increased payload/cargo carrying requirements. The enhancements to the SSME have the added benefits of increasing the robustness of the engines and have the potential for reducing the number of mandatory inspections between flights. In addition, if the present weight reduction effort falls short of its goal, then a greater engine thrust level will be required to lift the heavier payloads into orbit. Once the Block II engine program is completed, modest engine thrust level increases could be utilized to compensate for the added launch weight requirements. The Block II engines will be robust enough to tolerate these increased thrust levels and still provide an increase in reliability. Many of the other changes at this time are still in the "what if" category and need further assessment. The Panel plans to be fully briefed on the total enhancement program and integration effort during our visit to Johnson Space Center tentatively scheduled for mid-July of this year.

QUESTIONS SUBMITTED BY
THE HONORABLE F. JAMES SENSENBRENNER, JR.
(continued)

Question 5.

Mr. Parmet, are you aware of any internal assessments made of shuttle schedule required to support station assembly?

Answer 5.

As I understand the organization, the Vehicle Office within the Space Station Program Office at Johnson Space Center has the responsibility to conduct internal assessment of the Space Shuttle capabilities required to support the Space Station assembly sequence. This assessment would include any changes in the Space Shuttle manifesting schedule as well as any schedule impacts resulting from delays on the part of the International Partners or Russians. Assessments are continually being made within the Vehicle Office, to evaluate and plan for possible schedule contingencies. The ASAP usually obtains copies of the latest assessments and manifesting schedules during Panel visits to Johnson Space Center and the Space Station Program Office.

QUESTIONS SUBMITTED BY THE HONORABLE RALPH M. HALL

Question.

What are the indicators that will tell us when Shuttle safety is being jeopardized--how will we know when safety is being compromised?

Answer.

There are any number of data bases being accumulated which can be processed to show trends but the bottom line is this...the people who are in the direct line of processing and management are your best indication of when safety is being compromised. There are no statistical methods or analyses available that will tell you when you have cut too much. Unfortunately, with safety when you know for sure that you have gone too far it is too late. The people involved are and always will be your best source for information when safety has been compromised. This is why the ASAP has a task team which periodically surveys the personnel involved in Space Shuttle processing. I can tell you that the people at Kennedy Space Center are and always will be some of the most dedicated employees in the space program, but there is a feeling of uncertainty and a loss of morale which if allowed to continue may well impact safety. A missed step in a procedure or a system out of configuration could lead to serious consequences. It is a credit to the people involved that this has not occurred thus far. NASA needs a period of stability to assess how to manage its available assets and not be continually being asked to do more with less. NASA should be allowed time to determine how well it has been able to absorb the existing manpower reductions before it is asked to make additional reductions in critical areas. Certainly there are some areas that should be looked at, such as design engineering, to assure that the needs of continuing engineering support are met and at the same time de-emphasizing the need for the size and scope of an original design group.

QUESTIONS SUBMITTED BY
THE HONORABLE SHEILA JACKSON LEE

Question 1.

Do you feel that NASA has the proper safety guards in place? If not, explain. Please explain impacts of the proposed NASA restructure as it relates to safety, impacts to schedule, etc..

Answer 1.

I believe that NASA has today the proper safety guards in place for the program as it is organized. Whether future safe guards will be adequate or proper for the restructured program is difficult to assess until the full extent of the restructured program is known. The biggest impact from restructuring and reduced budgets

Question 2.

What impacts would you expect the proposed single contractor will have on the quality, or timelines of work produced by NASA?

Answer 2.

It must be recognized that the Space Shuttle is not and probably never will be a fully mature and operational vehicle similar to an airplane being operated by a commercial airline. However,if done correctly, the introduction of a single contractor to operate the Space Shuttle should have little or no impact on the quality or timelines of the work involved. It should be pointed out that the vast majority of the tasks presently supporting preparation of Shuttle are performed by contractor personnel and not NASA civil servants. The consolidation of Shuttle operations and overall management under a single-business entity may reduce the time required to process the vehicle and payload and thereby the overall costs by eliminating duplication in some areas and combining operations on others. It follows that in doing so, labor costs would automatically be reduced. How the prime or single-contractor concept would be actually implemented is unclear. Will this single-entity be an integrating contractor or a true prime with total responsibility for all systems? The question also arises as to liability and government oversight responsibilities. There is a real danger that the Shuttle would be treated as a mature system and operated more as a commercial airline than as a space vehicle. The assumption that reliability and redundancy can be used as excuses to relax safety requirements is not necessarily correct. There is a real concern that a critical safety item may be overlooked in an over-zealous desire to change the existing system in the name of cost savings.

QUESTIONS SUBMITTED BY
THE HONORABLE SHEILA JACKSON LEE
(continued)

The crux of commercialization of the operational aspects of the Space Shuttle relate to the following:

1. How the change will be accomplished

2. Full assumption of operational responsibility and liability by the single-contractor

3. Retention of the design responsibility by NASA

4. Definition and documentation of a set of operating ground rules

5. "Who" is responsible for "what" at the time of launch

6. NASA retention of audit and oversight responsibility (including veto powers)

QUESTIONS SUBMITTED FOR THE RECORD BY MR. KOHRS

QUESTIONS FROM
THE HONORABLE F. JAMES SENSENBRENNER, JR.

1. Should NASA be investing more in technology which could help reduce shuttle operating costs? In what areas do you see potential near-term payoffs from such investments?

> The cost of technology to offset operations costs needs to be cost effective. I believe cost effective technology gains can be implemented in areas of inspection during manufacturing by statistical inspection techniques. This expertise is being implemented by the manufacture of the Solid Rocket motor and these techniques can also be applied to Shuttle processing.
>
> Also, I believe that more effort can be invested in the paperless technology for vehicle processing. The immense amount of paper required to document checkout requirements, and verification could be simplified by more rapid introduction of computer controlled procedures and verification of completed work by utilizing electronic methods.

2. There have been innumerable studies throughout NASA performed recently among which was the Functional Workforce Review. Are you satisfied that these studies have been integrated or complimentary? Have they used a building-block approach to provide the necessary continuity?

> The Functional Workforce Review was composed of 12 independent teams. The integration of these teams was accomplished by the Shuttle Program Director over a four month period. I feel that this activity was integrated.
>
> The other studies such as the independent Shuttle Management Review (Dr. Kraft), the Federal Laboratory Review, the Headquarters Workforce Review, the Red Team Review, etc., are being integrated by a NASA Zero Base Review team. This approach as outlined should provide an integrated set of recommendations. I would expect that the findings and recommendations of the Zero Base Review team will be thoroughly coordinated with the programs/projects before proceeding with any implementation.

3. In the course of the study in which you participated, was there close consultation with the station program? Was enough attention given to the shuttle flight schedule required to assemble the station?

> There was no close consultation with the Station Program from my vantage point. The 12 teams of the Functional Workforce Review concentrated on Shuttle. In some cases, the teams did identify potential overlap.

My personal opinion is that Shuttle operations and Station Operations should be combined under one management structure as soon as possible (within the next six months).

The Shuttle flight schedule supports the Station manifest. I believe that the Shuttle performance requirement to meet the Space Station payload requirements is an area that needs to receive continued management attention.

4. What will the impact be on the space station and the station budget if a shuttle launch fails to go on time?

A delay in a Shuttle launch will have a cascading effect on the completion dates of major milestones.

The immediate effect is not a cost increase to Station or Shuttle in the budget year of the delay. The cost will be reflected in out year budgets.

5. Mr. Kohrs, are you aware of any internal assessments made of shuttle schedule required to support station assembly?

My experience within NASA is that the manifest planning group is continually working "what if" scenarios for the Shuttle manifest. I am not aware of any specific results, if any, from this activity.

QUESTIONS FROM
THE HONORABLE RALPH M. HALL

1. One of the justifications for privatizing the Shuttle is that it would allow dramatic reductions in civil service manpower, with associated cost savings. If the final launch approval authority is vested in a government representative, how do we ensure that the representative has sufficient visibility into a privatized Shuttle program to make a meaningful launch decision?

> Although civil servant manpower may be reduced if the Shuttle is privatized, it is not clear to me that overall costs of operating the Shuttle will be reduced. The first and most important aspect of privatizing the Shuttle is that the government (NASA as lead) and the contractor's must agree on the roles and missions of the government versus the contractor's. Today, the government civil service workforce is the integrator. The government civil service staff provides astronauts, approves mission operations launch and flight rules, provides launch and flight directors plus the civil service teams to lead the contractor activity. The civil servant team is responsible for overall safety, reliability, and mission assurance.
>
> If the contractor's assume the government responsibility and the government (NASA) in the final launch approval authority there will need to be a substantial oversight group that verifies the contractor's performance. This activity is not only limited to launch approval. It must deal with mission planning, on orbit operations, problem failure analysis and satisfactory resolutions, etc.

QUESTIONS FROM
THE HONORABLE MS. SHEILA JACKSON LEE

Panel II

1. Do you feel that NASA has the proper safety guards in place? If not, explain. Please explain impacts of the proposed NASA restructure as it relates to safety, impacts to schedule, etc...

> During my involved activity with the Functional Workforce Review teams, I was satisfied that the teams verified no safety holes were identified from previous workforce reductions leading up to the Functional Workforce Reviews which began in August 1994. There are proposals within the Shuttle Functional Workforce Review recommendations that if implemented without a thorough program review and program commitment could increase Shuttle safety and schedule risk.

2. What impacts would you expect the proposed single contractor will have on the quality, or timelines of work produced by NASA?

> Before a proposed single contractor approach is implemented, there must first be an agreement on the roles and missions of the government (NASA) and the contractor. I don't believe responsibility for overall safety, quality, schedule, etc., should be the responsibility of a single contractor. The government must maintain a role in management of the U.S. civil space program.

Subcommittee on Space and Aeronautics
Formal Questions for
the NASA Outside Opinion Panels
March 16, 1995

Submitted by
Dr. Maxime A. Faget
Space Industries International, Inc.
April 19, 1995

Panel I

1. *If Congress proposed a Flat Budget for NASA, explain the impacts that you would expect from NASA as it relates to programs, reduction in force, impact to schedule, safety, etc.*

   With the present budget level NASA has been required to eliminate almost all new programs. There has been a significant reduction in contractor manpower and a relatively smaller reduction in the civil service. Based on past experiences the Space Station program may need significantly more money in the coming years. If this cannot be avoided the program will need to be stretched or other programs will be impacted. Dan Goldin has been able to effect cost savings in the Shuttle program. Hopefully he will be able to compensate for some of the future budget crunch by achieving further savings in the Shuttle program without compromising safety.

2. *Is it feasible for NASA to consider restructuring without taking large cuts in the civil service and contractor work force in order to meet budget objectives?*

   One way or the other the entire NASA budget is almost all spent on manpower. A reduction or cap in the NASA budget therefore represents a reduction or cap in the money spent on wages or salaries in the civil service work force or the contractor work force be it at first, second or third tier etc. level.

3. *Do you feel that NASA can restructure the agency without impacting safety practices that were put in place after the Challenger accident?*

   No, but some of these safety practices should be discontinued. I believe that many of the safety practices that were put in place with good intent have proven to be perfunctory and perhaps punitive.

4. *Do you feel that NASA is over emphasizing the safety as it relates to restructuring?*

   I believe that safety has been over emphasized in the recent past. I am not sure how far NASA will be able to go in eliminating unnecessary safety activity as it restructures. Small steps have already been taken. It may be very difficult for NASA leaders to expose themselves to reproachment by eliminating perfunctory safety activity regardless of the benefits that might be obtained.

Subcommittee on Space and Aeronautics
Questions Submitted for the Record
The Honorable F. James Sensenbrenner, Jr.
for the Hearing March 16, 1995
for Dr. Maxime A. Faget

Submitted April 19, 1995

1. *Dr. Faget, you recommend that clear identification of responsibility will more than compensate for reductions in redundant personnel. Is this an endorsement of the structured surveillance program?*

   It is my opinion that there are too many people involved in safety and safety related organizations. Furthermore, I believe safety could be improved by reducing the perfunctory activity now associated with safety and holding the working organizations and personnel accountable for flight readiness. The message to these people would be a clear indication of trust and responsibility that would give them incentive to make the vehicle ready as well as to self check and overview the activity to assure readiness. This is exactly what every airline's ground crew does routinely. The structured surveillance program represents a small initial step in the right direction.

2. *Can you give us your opinion of the move toward a prime contractor for the shuttle? Is this a transition that can be accomplished while conducting flight operations?*

   I believe that placing the entire shuttle program under the management of a single prime contractor would be a very good move. It should not only decrease costs, but should also improve safety. This will only be a positive move if NASA at the same time speaks to the contractor with only one voice of authority. I am recommending that NASA in monitoring the contractor's activity, funnel all sources of inputs (from the expertise in various organizations) in a coordinated manner through a tight and effective contractor management organization.

   The transition could be best accomplished by choosing a prime to lead a team of other contractors chosen from the present providers. This would not only reduce the cost and time of changing contracts, but would also minimize the confusion at the working level. Since the total work force after completion of transitions would be smaller than the ongoing work force there should be little or no concern for identifying and hiring trained people. There would, of course, be the potential of a major problem of morale associated with layoffs. However, it must be realized that the intent is to reduce cost and streamline the organization. This can only be done with a reduction in work force. Properly planned and managed such a transition could take place with very little impact on flight schedule. If this is to be done it should be done as rapidly as possible. To this end, NASA should consult and work with the major contractors to come up with an effective plan for restructuring, seek requisite Congressional and Executive authority and do it.

QUESTIONS SUBMITTED FOR THE RECORD
THE HONORABLE F. JAMES SENSENBRENNER, JR.
FOR THE HEARING MARCH 16, 1995
FOR DR. MARK

1. If shuttle operations could be contracted out, what do you see as the relationship between NASA and the contractor? For example, how would industry likely respond to the question of liability for any accident that might occur? Would industry insist on an absolute indemnification by the government? Would the contract need to be a cost-reimbursement agreement or would the contractor likely commit to a fixed price? How could NASA ensure the integrity of launch decisions?

2. If commercial customers as well as the Department of Defense do not have the necessary confidence in the shuttle system to use it the way it could be used, how would you recommend this be changed? Can this change come about only with privatization or are there near-term measures which can be taken?

3. You have stated that there will never be an ideal time for the process of privatization, that someone can always find a reason for delaying change "after the next evolution." Do you base this observation on historical data, or have you reached this determination after a careful review of requirements for station assembly?

4. One of the most difficult areas in the discussion of shuttle privatization is liability. We are talking about incredibly expensive hardware and, frankly, the potential for enormous catastrophe. What are your views on this?

Answers to questions submitted for the record at the hearing of the Space and Aeronautics Subcommittee on March 16, 1995.

1. There are a number of contractual vehicles that could be used. I would start with a cost-plus contract and then move to a fixed price once people outside NASA gained a more detailed understanding of shuttle operations. Finally, the relationship could evolve to COMSAT like arrangement in which the government would be a stockholder in an essentially private organization. NASA would insure the integrity of launch decisions in the same way that is now done with other contractor operated launch vehicles such as the Titan launch system. When I served as Secretary of the Air Force (1979-1981), we turned over the entire operation of the Titan system to a contractor (The Martin Company). There have been no problems assuring launch integrity subsequently. There is no doubt that this can be done with the Shuttle as well. (I will defer my comments on liability for the answer to the fourth question.)

2. The reason why the shuttle is not used for commercial and military launches is that a policy directive prevents it. It is not a matter of confidence. In the early days of shuttle flights when I was involved (1981-1984) in NASA's management, there was a confidence problem. The loss of "Challenger" in 1986 re-enforced the arguments of those who did not want to put their payloads on the shuttle and this eventually led to the policy directive I have mentioned. The most important near term measure that could be taken is to revoke the policy directive that would permit putting commercial and military payloads back on the shuttle just as we did in the early days.

3. The basis for the opinion I expressed that there is no "right time" for any management change is based on history, experience and study of the current situation. First, history: I remember when the first reductions were made in the Apollo program in 1969, there were several high level NASA managers of that program who said that safety of flight could not be maintained with a flight rate of loss than eight per year. They were wrong. We flew three or four times a year successfully. Second, experience: When we instituted the shuttle processing contract in 1983, there was vocal opposition to turning this important function over to a contractor. Safety and "integrity" were two of the arguments made against the processing contract. The contract has been in place now for twelve years and is clearly successful. Finally, study: I have carefully examined NASA's continually changing plans for the construction and deployment of the Space Station. The most recent iteration - two or three months ago - was the insertion of more EVA in the deployment

process (This is something I have been urging for a long time). The use of more EVA is clearly a step in the right direction but I mention this only to demonstrate that I have been following NASA's plans for Space Station deployment in some detail for many years. There is absolutely no doubt in my mind that the Space Station could be easily, appropriately and safely deployed if the shuttle were operated by a contractor.

4. There is ample precedent for dealing with liability in high risk government sponsored operations or in government assumption of high risk liabilities incurred by private corporations. In the first case (government contractors), I would suggest that you examine the contract that the government has with the University of California to operate the nuclear weapons laboratories at Livermore and Los Alamos. In the case of private companies, an examination of government liability assumption in the case of accidents at nuclear power plants owned by private utility companies would be useful. I believe that both of these cases would provide guidance for how one might deal with the question of liability if the Shuttle operations were turned over to a contractor or completely privatized.

House Committee on Science, Subcommittee on Space and Aeronautics

Answers to questions submitted for the record, The Honorable F. James Sensenbrenner, Jr., for the hearing held March 16, 1995.

Jerry E. Pournelle, Ph.D., Chairman

Citizen's Advisory Council on National Space Policy

1. What is the most important cost-saving contribution of a reusable launcher compared with expendable launch systems?

Reusable systems should be designed for minimum cost operations, not maximum performance regardless of cost. Learning to design for operational simplicity cuts costs. The cost of the Shuttle, which is only partly reusable—most of it is 'refurbishable'—is in large part due to the huge standing army required for its operation. Since Shuttle was designed to employ a large number of people this is hardly surprising, but it's not going to get us low cost to space.

It takes the same fuel to fly a pound from Los Angeles to Sydney, Australia as it does to put that pound in orbit. Since airlines typically operate at a small multiple of fuel costs, and rocket operations need not be more complex or costly than airplane operations, costs to orbit ought not be more than double or treble those of airline operations. (They ought to be about the same, but airlines have had a long time to learn efficient operations. There's no comparable experience in space.)

Of course all this assumes that when you fly to Australia they don't push the ship off the runway into the sea and start over.

It also assumes that you don't need a 3,500 to 5,000 person ground crew to refuel the ship. If airlines in the U.S. had to employ 5,000 people per airplane in order to reuse one, they might find it cheaper to throw the plane away after a flight. Shuttle has that absurdity built into it. A genuine Single Stage to Orbit ship would not.

Operations design considerations include:

Small ground crew;
Savability: survive an engine out on takeoff;
Fast turn-around. Keep your ships flying, not in maintenance.

2. Is it appropriate for NASA to expect that the RLV program will replace space shuttle? Why or why not? When should NASA impose shuttle replacement characteristics or other requirements on the RLV program?

Shuttle will be replaced, but NASA shouldn't be operating the replacement.

In order to answer this question we must first define the role of NASA. The purpose of NASA is not to operate space ships any more than the purpose of the NACA was to operate airlines. NASA should ensure America's access to space by taking on technical development risks that are beyond the profit window of private industry. It should not compete with industry.

The US government should clearly specify the payloads—military and scientific—that must be put into orbit, and give a reasonable estimate of what the government expects to pay to have that done. Specifying how it is to be done, or by whom, is both needless and unfair. The Post Office doesn't specify the kind of airplane to use to fly the mail.

3. If the RLV program should not become a replacement for the shuttle, what should?

No replacement for the Space Shuttle is necessary or desirable. The Space Shuttle program will be as anachronistic in the 21st Century as the China Clipper flying boats were after World War II. Before 1940, the limited range of transport aircraft made an amphibious aircraft the best solution to transcontinental passenger flights. The flying boats effectively carried along their own runway in the form of their ship-like hulls, sacrificing payload for the ability to land at sea and thus island hop from harbor to harbor across the Atlantic and Pacific. After 1945, the advances in aircraft technology had increased aircraft range so that non-stop trans-Atlantic flights were possible.

The Space Shuttle design was driven by national security mission requirements to a size too large to permit complete vehicle reusability and low operations costs. The Space Shuttle was designed to be able to launch from Vandenberg Air Force Base into a polar orbit, dump out a large national security payload within minutes after achieving orbit, do a deorbit burn, then perform aerodynamic crossrange maneuvering during reentry to permit the Space Shuttle to land back at its launch point on the same orbit in order to minimize its exposure to the Soviet anti-satellite weapons system. This mission requirement drove the Space Shuttle away from its original "space truck" design to a larger, much more expensive vehicle. The original NASA Space Shuttle concepts had payloads of five tons to ferry crews and supplies to a space station, not the thirty-two ton national security payload requirements. The original Space Shuttle concepts would fly fifty to one hundred flights per year, carrying up pieces of spacecraft and space stations to be assembled in orbit. Rather than servicing space stations, the current Space Shuttles have effectively *become* space stations, capable of sixteen-day flights!

The next generation of space transport vehicles will come in a variety of sizes to support a variety of missions, much like air transport vehicles which range from Cessna light aircraft to ATR-42 commuter airliners to Boeing 737 medium jetliners to 747 jumbo jets. The U.S. government should not repeat the error of the Space Shuttle in trying to design a single vehicle to carry all sizes of payloads for all missions.

To repeat: there should be no "shuttle replacement," and NASA should be forbidden to study "Shuttle II" or "Shuttle replacement."

4. The X-33 is not intended to become an operational vehicle; it is a technology demonstrator. What are the principal technologies the X-33 should demonstrate?

Savability: multiple engines and the ability to save the ship given engine failure on takeoff (and at any other time in the flight). Losing an engine shouldn't mean losing the ship.

Fly often: ability to fly with minimum turn-around time. A design goal (not criterion, but goal) should be two orbital flights in one day. Note that the first flights will be sub-orbital. You don't have to 'make orbit or bust.' This lets you learn a lot from flying the ship. What's learned can be plowed back into improvements of the next model.

Fly higher and faster: fly in the thermal and aerodynamic conditions to be encountered on re-entry.

Fly soon: get hardware built and get it flying; don't generate endless mounds of paper and computer simulations. We have all the simulations we need.

Reusable structures. Cryogenic tankage. Light weight structures for space ships. Unexpected stresses. Effects of using engines to affect lift during re-entry. This should be an X ship; it should examine the edge of the knowledge envelope.

5. Is it necessary for the X-33 to achieve orbit, or can as much be learned from demonstrating a sub-orbital system?

It should be designed to achieve orbit if everything goes right; but provided that it is:

o Savable
o Flies often
o Flies soon
o Flies higher and faster, into the reentry flight regime

then making orbit is desirable but not critical.

X-programs are by definition **high risk** programs. If they weren't high risk, there would be no reason for government to fund them. One learns from X ships by **flying** them. It is impossible to predict in advance what we will learn—if we could, we wouldn't have to build an X ship. The X-33 should not be scaled so that you can't possibly make orbit, but it must be understood that there will be many sub-orbital flights before orbit is attempted. The great advantage of ships like this is their ability to fly sub-orbital and be tested incrementally. The first flights won't go more than a few thousand feet up. We'll learn a lot just from those.

6. Do you believe the X-33 program is trying to do too much as an "Advanced Technology Demonstrator," versus a traditional x-vehicle development?

The X-33 as currently conceived doesn't seem to me to be an X vehicle at all. It's a prototype. The requirement that it be able to 'scale' or 'grow' to a ship able to put 25,000 pounds into space station orbit makes as much sense as insisting that the DC-3 be 'scalable' into a 747.

We do not know enough to design a ship optimum for putting 25,000 pounds into space station orbit, and it is imbecilic to insist that an X vehicle intended to generate real—as opposed to computer simulated—data on SSTO operations and characteristics be saddled with the requirement that it be able to grow or scale into something that can do it.

Let me repeat: an X ship is intended to investigate technologies, not test a prototype design. The purpose of X programs is to take risks to gain knowledge. If we knew all we'd learn from an X program it would be pointless to do it, and if we knew all the risks then we wouldn't need government participation.

An X project is not a subsidy to a commercial firm. It's a program to reduce technical risks, and learn about new technologies.

OBSERVATIONS:

The X-34 is not an X program and never was one, and ought not be given the dignity of an X designation. That ship should be called the Y-34.

The X-33 is close to becoming a "Shuttle II replacement" program. If it becomes that it would be better not to fund it at all. Let me repeat that. If the X-33 cannot be made into a genuine X project, then it ought not be funded.

The Y-34 appears to be a way to spend $70 million of government money to build an operational vehicle that will assist one company in garnering a monopoly on small satellite launches. This doesn't seem fair, and since it will kill all other small private launch ventures, isn't in the national interest. It is reasonable for the government to cooperate with all firms trying to get into the small payload business. That's the way NACA operated, and NACA was one of the spectacular successes of government/industry cooperation. The Y-34, by contrast, puts money into a single firm and freezes everyone else out of the small payloads market.

There is a move to say we should do the 'Y-34' before we do anything with the X-33. This is stupid. The Y-34 is a government subsidy to a commercial design. It is not an X ship, it isn't designed to stretch the technolgy envelope, and attempts to couple those programs are no more than a means to delay the X-33. This must not happen. It would be better to cancel the Y-34 entirely than to let it be the means of gutting the X-33.

The X-33 properly managed will be an important investment in America's future. It shouldn't be bogged down with Washington business as usual, but that seems to be what's happening to it.

WHY HAVE NASA?

Jerry E. Pournelle, Ph.D.
Chairman, Citizens Advisory Council on National Space Policy
Testimony to Subcommittee on Space

March 16, 1995

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This document has been revised to include answers to some questions asked at the March 16 hearings; in particular, why Shuttle made all the promises now made by SSTO; why is the SSTO program different from the Shuttle program?

A formal reply to questions sent after the session is attached.

THE PURPOSE OF NASA

NASA was a Cold War creation. Now that the Seventy Years War is over, why is NASA needed?

The potential of space is very great, but at present there is high risk and little immediate payoff. The major market for space services is government; while private markets will develop, they haven't yet, and probably won't until access costs are lower. There isn't a great deal of private incentive to bring those access costs down because the markets have not been developed. Lowering access costs and developing space markets requires a long term commitment. The return from that will be high, but it's in the future.

The discounted value of a dollar in 15 years is effectively zero.

What will you give me if I promise to pay you $1000 in 15 to 20 years?

It isn't reasonable for private companies to do long term investments.

Bell Labs where the transistor was invented was special and doesn't exist any more. There is nothing else like it. We have no institutions charged with long term technology development. This puts the United States at a distinct disadvantage, because not all nations have our limitations on futurist development.

We all know that sometime in the next century, space will be very important to the international economy. It's not rational for any private company to do space development research. Someone must. That leaves government.

Adam Smith held that enterprises in which the risk is high, the return to all is great, and the benefit to any one investor is problematical, are proper subjects for government attention. This is a good example: the return is high, but more to the next generation than this one.

The legitimate mission of NASA is to do long term technology developments in aeronautical and space sciences; and to make the results available to American companies for exploitation.

In other words, the purpose of NASA is to look ahead of the profit window and identify promising aerospace technologies for future development.

The way to demonstrate new technological discoveries and identify the technologies needing further research and development is through X projects.

X PROJECTS

X Projects incorporate state of the art technology into a project which focuses on a technological objective. Their mission is to stretch the envelopes of technological knowledge. They may achieve other results.

The primary mission of an X Project is technological.

An X space ship would not have a mission or cargo requirement beyond what is needed to achieve the technological objectives.

X Projects are not prototypes.

We don't expect to build a lot of them.

X Project craft are expendable.

We don't want to crash an X ship, but it can happen, and we cannot be so concerned about the possibility that we don't get on with the project. Typically three X ships are planned. One is often expended. The second is then flown given the knowledge learned by the loss of the first. Sometimes additional models are built to reflect discoveries made by flying the first ones.

X Projects are short term. Ships are planned, built, and flown. Then the project ends.

X Projects build upon each other. They may overlap.

The purpose of X projects is to demonstrate new technologies, learn about new capabilities, study operations with the new technologies, and discover new areas that need work.

X Projects may not lead directly to prototypes. It is a mistake to insist that they do so.

The best example is the X-1, which was intended to demonstrate the possibility of supersonic flight. Flying faster than sound was an elusive and costly goal. The X-1 was built with the single purpose of demonstrating that it could be done. There was no cargo other than the pilot.

The X-1 did what it was intended to do. It also gave new insights into the problems of flying in transonic regimes.

It was followed by the X-3 Stiletto, a plane that could not have been built when the X-1 was planned. The X-3 did lead to operational aircraft, including the F-104 Starfighter.

The X projects were greatly successful. They were effectively ended in the late 1960's. The X programs were not canceled in the name of economy. Knowledge gained through the X programs helped U.S. aerospace firms to dominate the world industry. In the 1970's US high technology, particularly aircraft, were the largest single cash export of the nation. They were very important in making up the deficits in our balance of payments.

The X projects were canceled because of arms control. The arms control strategy held that rapid development of military technology was undesirable since it led to 'new rounds in the arms race.'[1]

Whatever the wisdom of the arms control strategy in the Cold War, there is no arms race now. There is instead a new international competition which resembles the Cold War in that it is 'silent and apparently peaceful, but could well be decisive'. It is a new Technological War, and the United States has a great deal to gain from achieving not merely a leading, but a dominant position in all areas of technology. In particular, we can achieve a commanding lead in aerospace technology. The way to achieve that is through properly organizing NASA into the leadership agency in long term aerospace R&D, and reviving the X programs.

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[1] This strategy, along with our objections to it, is explained and discussed in *The Strategy of Technology : Winning the Decisive War* by Stefan T. Possony and Jerry E. Pournelle, University Press of Cambridge Mass., 1970. *The Strategy of Technology* has been used as a textbook at USMA, USAFA, and the Air War College.

SIDE BENEFITS

There are side benefits to X programs.

One benefit that may not be obvious is career continuity. Because commercial firms must look to short term profits, it is often necessary to downsize in unprofitable years, and hire extensively when business is good. The effect on high technology careers can be devastating. Our recent history looks like a bad parody of manpower resource allocation.

It takes a while to learn how to do aerospace engineering and project management. There is also value in having been part of a project team. X projects provide a small but significant number of technological people with continuity of employment doing something worth doing. Talent lost to the aerospace industry is generally lost forever.

X projects are a source of hands-on experience. They are not jobs programs; the X projects are themselves valuable. They are also fairly short term, and generally carried out in places like Edwards Air Force Base, China Lake, White Sands, and other areas unlikely to attract people who want to build bureaucratic empires. X programs generate a talent pool of experienced people likely to be hired away from government service into private industry at need, but available during periods of low economic growth.

Note again we are not advocating a jobs program; merely continuity of employment for a small number of key people doing important work. Think of a good X program office as the government's Skunk Works. Its very existence is a major plus factor in international competition.

LOW COST ACCESS TO SPACE

The key to space development is to get lots of people into space. Once they can get there, they'll develop markets. Bring resources, energy, and ingenuity together and the result has always been wealth. Space has resources and energy. What it doesn't have is entrepreneurs with access to the space environment.

There's no reason space cannot be a source of revenue. This is important when government runs at a deficit. If we're going to borrow money from our grandchildren, it's both reasonable and ethical to spend some of it on genuine investments. Space can be, but has not been, a place for genuine investment: that is, a potential revenue source, not a perpetual sink.

The way to get lots of people into space is to bring the cost of space access down by a factor of about one thousand. It can and should be brought down to costs comparable to long distance airline operations. In the next section we'll look at how that might be feasible. For the moment, consider what would happen.

There isn't much market for space services because the cost of getting there is so high. Even so, there are proposals for 800 + communications satellites, to be launched and maintained at the present ridiculously high costs, with the full expectation of profit. Weather satellites are worth the costs of putting them up. There are national security payloads that are worth present costs.

Not much else is. Hubble Space Telescope is returning some wonderful pictures, and there are numerous science experiments that give us very good data, but it's questionable whether the data are worth the costs. On the other hand, if space missions cost millions instead of hundreds of millions to billions, everything changes. The spacecraft themselves would be cheaper, because there would be no need to design them to last unattended and forever. Spacecraft tend to cost about the same as the operations costs of getting them up. This is sensible, but in our rapidly changing technology environment, the electronics in spacecraft are generally obsolete long before the spacecraft has ceased operations.

Future space markets are totally dependent on access costs. They are also unpredictable. Take an example from airplane days. Suppose in 1920 the

Congress had tried to form an intelligent estimate of the economic potential of airline travel; in particular the number of tickets that might be sold. One probable route would be New York City to Los Angeles, California. They might look at the number of people taking that trip by train. They'd then factor in the ease of travel by air as opposed to trains, and try to guess at a number. If they felt very bold they might decide that as many as 500 a week would take the trip. Then they could be extravagant and multiply that by two, to get 1,000 a week. They might even go mad and estimate ten thousand a week.

They'd never come close to the actual numbers on any reasonable or even sane set of assumptions, and even if they went mad and guessed the right numbers, no one would believe them, and they'd still not have a handle on the second order effects: the industries that are only made possible by rapid travel capabilities.

It's the same way with space. When space access gets down to the price of first class airline travel, it's nearly impossible to estimate the volume of business.

The simplest business is tourist travel. I have asked travel agents to consider an ocean trip to, say, Grenada, with the high point of the trip being four to eight hours in space—a round the world trip with a vengeance. How many would buy tickets depends on the ticket price, but even at $50,000 a ticket, the estimates of the number of tickets that could be sold are surprisingly high.

The story is the same with science and industry. Get the cost of space access down and the volume of traffic goes up sharply. A few years ago the cellular phone was science fiction. Then it was a status symbol. Now we can contemplate every citizen having a personal telephone number that doesn't change no matter where the temporary or permanent residence. In another generation that won't be a prediction but a necessity.

Twenty years ago G. Harry Stine described some potential space industries in his book *The Third Industrial Revolution.* I described others in my *A Step Farther Out*. None of these marvels came to pass because the cost of access to space remains so high; but given reasonable access costs those industries would develop very rapidly.

The military implications of low cost access should be obvious. "Information Warfare" is the new buzz phrase in the war colleges. Whatever it means and whatever you think of Information Warfare, one thing is obvious: if you are going to control information, you must control access to space, and you'll need to get there a lot cheaper than we do it now.

I have previously described the system I called THOR. Consider a tungsten rod about twenty feet long and a foot in diameter. Put it in orbit, and have a means to direct its reentry. Give it a terminal guidance system—fins, or use a means to move the center of gravity—and a Global Positioning System receiver. Don't bother with a warhead. The result will be a missile able to hit any point on earth with an accuracy of under 25 feet and a closing velocity in excess of 12,000 feet per second. The result is energies comparable to tons of TNT buried under the target. Few structures: bridge abutments, fuel dumps, anchored warships including both battleships and carriers, fuel dumps, hardened armor parks, etc., can withstand that.

Observation and communications satellites will be available to theater commanders on the same basis as AWACS flights.

All this is not only possible but inevitable with low cost access to space. The only question is who will get there first to take advantage of the space environment. At the moment the United States has a lead in space access, but other nations can do this analysis as easily as we can, and many have done so. Several are looking at ways to gain low cost access to space.

There is a way to reduce the cost of access.

SINGLE STAGE TO ORBIT (SSTO)

Airlines operate at a small multiple of fuel costs. This includes both flight operations and amortization of aircraft. It takes about the same fuel energy to put a pound in orbit as it does to fly that pound from Los Angeles to Sydney, Australia. Since rocket engines are as efficient as jet engines, there is no reason why space operations should cost more than two or three times what long distance air travel costs. In particular, you should be able to buy a ticket to orbit for no more than twice what it costs to buy a ticket to Sydney.

Of course airlines don't push the airplane off the end of the runway into the Coral Sea when the airplane gets to Australia; nor do they rebuild it. They do routine service, refuel it, and fly it back. That is what space operations must be like if we are to make access to space affordable to the American people.

The obvious way to go to space is to fly to space and return; to operate like an airplane. That wasn't possible with the materials and engines available in the early days of rockets. Nearly everyone is agreed that it is possible now.

We know that SSTO is possible, and we know how to build a single stage to orbit ship. However, we don't yet know how to design *operational* SSTO craft. We know we can build SSTO ships, and there are probably several ways that will work. Fundamental designs include: ships with wings; ships without wings; lifting body ships that take off vertically and land horizontally; ships that take off vertically and land vertically; ships that reenter nose first; ships that reenter tail first; and variants of the above. Fuels range from hydrogen to propane. There are several possible engine configurations.

Most—probably all—of these will 'work' in the sense that the ship will get to orbit; what isn't known is how much cargo the ship will carry. Note that I say cargo rather than 'payload'. Payload is a term that comes from the days when we threw the ship away: there was structure, which was bad, and payload, which was good. In those days ships were designed to maximize performance, and performance was measured by payload to orbit.

That is no longer the best way to design ships. SSTO ship designs should be driven by operations, not performance. Take space construction as an example. We can design ships to deliver one large payload; but suppose we can build the structure at far lower total cost by taking up smaller payloads at vastly lower costs per flight. Even if doing so requires redesign of our primary structure the resulting savings can be in the billions. This is what I mean by operational rather than performance driven design.

At the moment we can't really estimate operations costs, because we don't really know what SSTO payloads will be. The rocket equation—rocket science, if you will—says that the amount of useful cargo in a Single Stage to Orbit ship will be a third decimal fraction of the Gross Liftoff Weight (usually abbreviated as GLOW). That is, if I have a ship that weighs 500,000 pounds at takeoff, about 450,000 pounds of that will be fuel and oxidizer. Of the remaining 50,000 pounds, between 30,000 and 50,000 pounds will be ship structure and the fuel required to bring the ship home. What's left over is cargo delivered to space. That cargo can range between zero—none—and about 20,000 pounds, depending on how light we can make the engines, tankage, and structure of the ship.

However, it's not really as simple as that, because we aren't sure that we'll need the full 450,000 pounds of fuel and oxidizer; it depends on drag. Drag is the term used to describe air resistance as the ship rises. Drag is critical because it affects everything else. The lower the drag, the more quickly the ship will lift. The faster the ship lifts the more quickly it gets to higher altitudes. The higher the ship gets, the more efficiently the fuel burns in the rocket engines, and, since the air is thinner, the lower the drag.

In other words, my assumptions about drag are crucial to determining my predicted cargo.

We do not have accurate predictions of drag. We're going to have to fly some ships to get the required accuracy.

Similarly, we don't know some crucial facts about stresses which determine the structural mass of the ship. We need to fly ships to find out.

There are other unknowns. The bottom line, though, is that we need some more flight data before we can design operational Single Stage to Orbit ships. Until we have real flight data, the cargo—payload weight, if you prefer—is determined by the assumptions you plug into your computer model, and no one set of assumptions is markedly better than another.

SSX

We need an SSX-1; an experimental single stage to orbit space ship. That ship should be built to have these characteristics:

Be Savable

It should survive an engine out on takeoff.

Fly Often

It needs to be flown many times, including going to orbit twice in one day.

Fly Soon

Build the SSX with known technology. Its purpose is to identify what we need to know, not to be part of a longer technology development. We need some hard numbers about thrust and drag and control surfaces and command authority and other such technical matters. We need those numbers soon.

Fly Higher and Faster

SSX need not get to orbit, but it should fly high and fast enough to experience reentry conditions; and it should be designed so that if all goes just right it will make orbit. Orbital flight should not be precluded by the design. On the other hand, we shouldn't be concerned about cargo or 'payload.'.

Note that an SSX can be incrementally tested. The first flight can be partially fueled and last only a few seconds. After analysis of flight data you can fly again, this time higher and faster. The test series gives new data at each stage. By the time you do a maximum fuel and thrust test you will know a great deal more about the ship's capabilities.

Make the SSX *savable*, build it with a high safety factor, then reduce structural weight as flight test data show what are critical stress areas and what are not.

An SSX-1 program would cost about $1 billion and take about four years. While a billion dollars is not trivial, it's a pretty small investment in what we all know will, some day, be a business comparable to air travel.

HAVEN'T WE BEEN HERE BEFORE?

Shuttle Promises

The original proposal for Shuttle as a National Space Transportation System used many of the arguments now heard for Single Stage to Orbit. Shuttle didn't lower launch costs. Why will this be different?

Not Shuttle II

We don't here propose that NASA build Shuttle II, or any other kind of 'National Space Transportation System.' We don't believe that any single SSTO design can possibly become the national launch system any more than any single airplane design could become 'the national air transportation system.'

Shuttle was designed to employ about 20,000 people. It met that goal admirably; you can't fly Shuttle with fewer people. It just can't be done.

Airlines typically operate with about 110 employees per airplane, and about half of those sell tickets. High technology systems like SR-71 had about 50 people per airplane. Shuttle has nearly 25,000 (including contractors) for 4 orbiters. At an average of $100,000 per employee, we have a fixed overhead of over $2 billion a year. Assume ten flights per year and the cost is $250 million per flight before adding in variable costs like fuel, new engines, and other operations. Since Shuttle needs all those people, there's no chance of getting the cost per flight lower than, say, $350 million. Actual operations costs appear to be considerably higher than that. If Shuttle had 50,000 pounds of payload per flight then the minimum cost of a pound to orbit is about $7,000. Most estimates are that it's higher.

Operations Not Performance

Shuttle was designed under the older rocket design philosophy of maximizing performance. In the days of throwaway rockets and disintegrating totem poles this made sense; but it doesn't any more. We should instead design to minimize operations costs. If this means smaller payloads per flight, then so be it. Our new SSTO vehicles -- there will be more than one kind -- should be designed for operational simplicity and minimum operations costs.

X Systems, Not A National Transport System

We do not here advocate a new National Space Transportation System, or a new National Launch System. We don't believe there ought to be such things, and if there were, NASA shouldn't build and operate them. That isn't NASA's value to the American people.

Imagine a 'National Air Transport System': a single kind of airplane for all aircraft applications from crop dusting to long distance passenger sevice to logistics support of South Polar operations. Clearly that's absurd. It's equally absurd to postulate a 'National Space Transportation System.'

There must be no Shuttle II.

What we advocate is advanced R&D culminating in X ships; in particular the SSX. SSX will investigate technologies required for operational SSTO ships. We've listed the SSX characteristics before, but it's worth repeating them:

SAVABLE

Multi-engine ship that can survive engine out on takeoff.

FLY SOON

Get the ship flying within four years. Sooner if possible.

FLY OFTEN

Fly it a lot, through a number of flight regimes. Get it to space twice in one day.

FLY HIGHER AND FASTER

As high and fast as we can with easily obtained technology.

In addition to the SSX-1 program, there should be a parallel effort to develop a new engine. The new engine should be reliable and reusable like the RL-10; throttleable, again like the RL-10; and cheap. The RL-10 is not cheap at present because we buy very few of them, and there's no incentive to make them cheaper. It wouldn't be hard to get their costs down: simply commit $40 million to buying RL-10 engines and ask for competititive bids on how many can be supplied for that price. You will certainly get more than 100 for that price.

NASA can then use these engines in X Space Ship programs. It cannot be too often stated that X ships are neither operational ships nor prototypes of operational ships.

Let Industry Choose the Operational Ships

NASA shouldn't be an operating agency. NASA shouldn't be flying the ships. Why should NASA dictate ship design? NASA should develop new technologies, and let industry design and operate the ships. Certainly NASA ought to cooperate with industry in selecting what technologies ought to be developed; but that's not at all the same as doing the actual designs.

We already know how to build Single Stage to Orbit ships. We don't yet know the best designs for operational SSTO. Let NASA investigate the technological unknowns. Industry will do the rest.

SPACE STATION

Space station as presently conceived has few potential tenants.

It remains one of our few high technology R&D programs.

The proper way to think about Space Station is as a learning process: as a series of X projects designed to develop space construction technology.

In particular, Space Station should be designed to make use of on-orbit assembly by assembly crews: not by Ph.D. astronauts, but by the equivalent of deep sea oil riggers. Working on an oil rig platform is hard and exacting work, and deep sea assembly is every bit as technically challenging as capturing a satellite in zero gravity; but we don't insist that everyone who works on an oil rig have a Ph.D. in Aerospace Science from MIT. Space station should begin the process in which all Americans get a chance at space access.

If Space Station becomes a series of space construction X projects we will learn about station construction; US industries will regain the lead in orbital technology. That is the proper use of Space Station. Stop worrying about its missions and who will make use of it; use it as a means to regain American leadership in space construction experience. Space is an environment we need to know more about. Use Space Station for that.

Simultaneously, we must continue the X programs that lead to low cost access to space; and we have to learn how to supply space installations at reasonable costs with operationally affordable payloads. Seen properly, Space Station is part of our overall strategy to gain a commanding lead in space operations technology.

NASA DO'S AND DON'TS

NASA should stop worrying about Shuttle Replacement. Something will replace Shuttle, but it won't be a single "National Transportation System" nor should whatever it is be operated by NASA. Many parts of NASA have been obsessed to the point of paralysis by what they perceive as the problem of Shuttle II. They should be told to stop thinking about it and get on with the primary mission of NASA.

NASA should be forbidden to plan Shuttle Replacement Systems. That is the only way to end NASA's obsession with Shuttle II.

NASA should get out of the flight operations business. This means Shuttle I. It also means Shuttle II. As a general proposition, by the time we know enough about space transportation systems to design an operational system, we know enough to turn that problem over to the engines of free enterprise. In the past NASA has stifled free enterprise by trying to keep a monopoly on space operations—to own the "National Transportation System." That must never happen again.

NASA should remember that it is also the primary long term R&D agency for aeronautical systems. NASA and before it NACA had a long and admirable record of facilitating aeronautical developments through provision of wind tunnels, ranges, and other test and analytical facilities. They should renew those activities.

The NACA model should also be the model for space development.

NASA can, by focusing on R&D in space technology, be instrumental in aiding US industry to provide the American people low cost access to space; and to giving US industry, and thus the United States, a commanding lead in what Speaker Gingrich has called "The Greatest Frontier."

NATIONAL
SPACE SOCIETY

April 5, 1995

The Hon. F. James Sensenbrenner, Jr., Chairman
Subcommittee on Space and Aeronautics
Committee on Science
2320 Rayburn House Office Building
Washington, D.C. 20515

Re: March 16 Hearing on *NASA: The Outside Opinion*

Dear Mr. Chairman:

Thank you for inviting the National Space Society to participate in the subcommittee hearings on NASA, and in particular the aeronautics and technology panel. I hope our views will be helpful and we look forward to being of assistance in the future.

At your request, I would like to suggest some corrections to the hearing transcript and provide responses to questions submitted for the record.

Corrections to the Hearing Transcript

Page 111:

Line 2336 - "The National Space Society **advocates** key enabling...."

Line 2341 - "potential for water ~~rights~~ **ice** on the moon...

Page 112:

Lines 2355-2358 - "The National Space Society has advocated several ~~such~~ mechanisms such as vouchers, prizes, **and** tax exemptions for space activities. We believe **in** these kinds of steps, **but** frankly they are experiments."

Lines 2375-2376 - "sometimes known as the ~~"Think"~~ **"Fink"** report. And~~, one of~~ the number one recommendations of the ~~Think~~ **Fink** report was...

Responses to Questions for the Record by Scott Pace

1. How does NASA view its space technology base in comparison with DOD's view of the space technology base?

While we cannot speak for NASA or the DOD, it has been our consistent impression that they view space technology differently. The DOD takes a very systematic approach towards identifying needed technologies, cultivating the domestic industrial base, and takes

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technical risks to achieve new operational capabilities. The DOD has made increased efforts in recent years to take greater advantage of commercial technologies and adopt efficient commercial practices in the defense industrial base. The decline of the DOD budget in recent years has meant, however, a decline in innovative risk-taking as ARPA, BMDO, and the Department of Energy, have scaled down their space activities.

Despite the detailed structures of Program Operating Plans (POPs) and Research and Technology Operating Plans (RTOPs), NASA does not have an effective systematic approach to the development of new technologies, and the cultivation of a strong domestic space industrial base. In part, this comes from the NASA tendency to focus on projects rather than new operational capabilities. The development and qualification of technology may be done for a specific mission, but rarely as part of an on-going effort to put new items "on the shelf" for use by others. Space qualification procedures discriminate against the adoption of new technology in favor of technology which has been flown. Rather than worry about the state of the space industrial base as a whole, there tends to be an attitude of "we can procure whatever we need." This assumes, of course, that money is no object.

An additional problem is that NASA satellites tend to be hand-crafted items, built in lots of one or two for unique missions, rather than part of on-going production lines that can be improved over time. In fairness, the unmanned satellite side of NASA does better than human spaceflight in terms of inserting and proving technologies for space applications. The understandably stringent safety and quality assurance procedures of NASA make it very difficult to incorporate new technologies, no matter what their record in the commercial world outside of NASA.

2. How effective is NASA at expanding and improving the space technology base?

Past NASA efforts such as Pathfinder and the Integrated Technology Plan were cut in budget exercises that favored current operations, overhead, and new project starts. The most recent NASA effort to demonstrate new technologies, the New Millennium Initiative, is a positive development and we wish it well. We are concerned, however, that short-term budget pressures are reinforcing NASA tendencies to prefer high-visibility demonstration projects over the steady development and flight qualification of new technologies, components, and software that could be used by the entire space community.

If an R&D organization is its own customer and peer-review is the sole means for selecting ideas for support, then it tends to get incremental improvements and not breakthroughs. This is a problem recognized in non-space technology organizations as well as in basic research. NASA needs to look beyond itself for customers just as DOD research organizations look to military commanders to be the ultimate users of their work. The reality of competing ideas to meet the needs of an external customer imposes a clarifying discipline that improves productivity.

Taking a lesson from the DOD, we think NASA would benefit from establishing measures of effectiveness that go beyond individual space missions. As suggested in our testimony, we think that two of the most important questions NASA could answer are: 1) can humans "live off the land" in space; and 2) can humans produce things of value in space to pay their way. These sorts of top-level questions are consistent with the 1988 Space Settlements Act which looks to the establishment of permanent human settlements in space. Moving down from general goals to specific actions, NASA could work with other government agencies and industry to advance the state of the art in key technologies such as lightweight propulsion, batteries, solar arrays, life support, and non-terrestrial materials processing.

3. Is NASA making the best use of space technology developed outside NASA, particularly that developed by DOD and in the private sector?

The short answer is no. NASA has missed many of the key space technology developments of the past decade, from distributed telecommunications architectures, to low cost remote sensing and satellite-based navigation (e.g., GPS), and innovations such as hybrid propulsion (developed first by American Rocket) and air-launched rockets (e.g., Pegasus was begun through ARPA). NASA's technology efforts are spread very thin and too rarely used to leverage their core programs. For example, the Space Station is not using the advanced solar arrays that have been demonstrated on DOD missions. As I mentioned in testimony, microprocessors only got aboard the Space Shuttle as a flight critical item in 1990. This situation is not the result of any specific failures by NASA personnel, but the natural result of too little competitive pressure. In commercial and military fields, the sources of competitive pressure are usually obvious. In the case of civil spaceflight, competitive pressures can be simulated when an agency is given challenging assignments beyond their immediate capabilities (e.g., a landing on the Moon).

We recognize that there is an inevitable tension between building new products, such as satellites, and adding to the less glamorous but vital technology base. Both activities have merit and we suggest that a small but firm budget fence be put in place for technology development and space qualification just as basic research is given a fixed base to plan on.

Rather than building itself around projects that take decades and utilize field centers across multiple states, NASA might adopt more commercial-like "portfolio" approach in which it undertakes a spectrum of activities, some more risky than others, to achieve advancements in the state-of-the art and the state-of-practice of space technology.

4. How might NASA improve its ability to "spin-on" technology?

NASA's conduct of civil space missions in recent years has too often been as a consumer of technology, not a creator. Commercial or military technologies that have long proved themselves in non-space applications are only slowly qualified and accepted for spaceflight. It is difficult for individual firms to justify the cost of this type of work for small product lines. As a positive example, the Lewis and Clark missions are qualifying and proving several component technologies in the bus for the first time. These are not really "new" technologies, but they are new to being used in space.

The National Space Society believes that it is an appropriate function of NASA to work closely with U.S. industry to identify and routinely qualify new technologies for spaceflight as a benefit to the nation that would not be done by the private sector alone. We suggest the following steps to improve "spin-on" and strengthen NASA's ability to contribute to the nation's space technology base:

- Make greater efforts to separate the conduct and funding of R&D from operations. Budgets for NASA R&D should be made more easily identifiable; which is difficult given the way NASA combines costs into common Research and Program Management (RPM) accounts

- Provide steady support for the development and qualification of new space technologies, components, and software separate from any particular flight project. Encourage a more systematic approach to identifying gaps in the space technology base that directly involves industry and other agencies with space activities, such as DOD.

- Require more "joint" space activities, not just between military services, but between NASA, DOD, and DOE as well. This need not include major system developments, but rather multiple, small efforts to advance common technologies. The most effective form of technology transfer is people working together and this means greater interchange between NASA, DOD, academic, and commercial space technologists. Let me emphasize this point: it is important to work together on real hardware that will actually be tested. Just serving on the same review boards, study groups, and conference panels is not enough.

Ideally, NASA should measure the strength of its technology programs not by the size of its budget, but by the spread of improved technologies into scientific, commercial and military space missions. It would measure its successes not by the number of NASA satellites flown, but by the quality of prospective partners willing to work together to extend human activity deeper into space.

Thank you again for inviting the National Space Society to participate in these hearings. Please feel free to contact me if we can provide additional information or otherwise be of assistance.

Sincerely,

Scott Pace

Scott Pace
Chair, Policy Committee

QUESTIONS SUBMITTED FOR THE RECORD

BY MR. SPITZER

Responses to Fourteen Questions asked by
Representative Van Hilleary
House Science Committee
Subcommittee on Space and Aeronautics
Hearing on NASA: The Outside Opinion
Panel #4 Aeronautics & Technology
U.S. House of Representatives

Reference: (1) "New Subsonic and Transonic Wind Tunnel Complex", Industry Briefing Paper prepared for interested parties, dated July 1994.

(2) "Fiscal Year '96 NASA Aeronautics Research & Technology Budget Authorization Hearing," Robert Spitzer, Vice President of Engineering, Boeing Commercial Airplane Group, The Boeing Company, dated March 16, 1995.

#1. In the area of aeronautical technology related to commercial transport aircraft, there was a period of time spanning several years when Boeing considered the wing aerodynamics technology of the newer Airbus aircraft to be superior to that of Boeing. A principal factor that enabled Airbus to achieve that lead was that they conducted their wing development work in wind tunnels that provided higher Reynolds number flow than the wind tunnels that Boeing had been using.

Boeing responded to the situation by mounting a concerted wing aerodynamics research program carried out in wind tunnels that provided increased Reynolds number in conjunction with facility productivity levels that allowed progress to be made at a reasonable pace. The result was that in the span of about six years of dedicated wing technology research, Boeing achieved the ability to design wings having aerodynamic performance that was judged to be nearly comparable to Airbus. This ability is only achievable with access to high Reynolds number wind tunnels.

The experience of finding ourselves behind Airbus in wing aerodynamics technology provided the impetus for Boeing to advocate the development of the proposed National Wind Tunnel Complex.

Additional material can be found in Section 3.2 of Reference 1 (pages 6 - 9).

#2. The Europeans have built six new wind tunnels to improve substantially their experimental Reynolds number capability. They have used that capability, superior to the U.S. counterpart, to establish superiority in a number of aeronautics technology areas. The Russians presumably have the same intent, although they have not yet been able to convert their new experimental capability into superior aerodynamic technology.

Section 4.2 of Reference 1 (pages 13 and 14) addresses the relative U.S. and European wind tunnel competitive positions.

#3. The U.S. industry position is that the new wind tunnels are urgently needed to halt and reverse the decline in the U.S. position in aeronautics technology. This is required, in turn, to halt the loss of market share to the non-U.S. aircraft industry. Reference 1 has been produced by industry, and explores many issues on this subject.

#4. Boeing did indeed carry out much of the development work on our new 777 airplane in European wind tunnels. McDonnell Douglas also uses European facilities. The Boeing experience has made us acutely aware of the concerns and risks associated with being dependent on a critical facility that is not under control of the United States.

First of all, it eliminates any opportunity for the U.S. industry to gain a competitive advantage by testing in facilities that could be superior to those available from the competition, either in terms of Reynolds number capability or in terms of productivity and time-to-market. At worst, we could be prevented from using a key facility that is occupied and/or controlled by Airbus. That would put us at a critical disadvantage.

The other aspect of deep concern to us is the ability to control the access scheduling. The basis of competitiveness of the airplane industry, both commercial and military, is shifting in the direction of recognizing cycle time, cost, and variation as key elements of competitiveness. Boeing, McDonnell Douglas, and Airbus are engaged in a race to reduce cycle time, cost, and variation associated with the processes we use . Therefore it is becoming increasingly important for the United States to be able to control the access scheduling of high Reynolds number wind tunnels that are key to designing competitive airplanes. If access scheduling is controlled by Europe, that can be used as a weapon against us to drive up our costs and time-to-market, which are critical factors for competitiveness in the world of tomorrow.

Issues of competition and national security in wind tunnel use are also addressed in Section 5.3 of Reference 1 (page 17).

#5 Traditionally, U.S. Government has provided wind tunnel facilities for U.S. industry to use. In recognition of tight federal budgets, innovative schemes for financing the new national wind tunnels are being explored. These included participation by industry (10% of cost) and possibly by local and state governments. These issues are addressed further in sections 7.4 and 7.5 of Reference 1, pages 21-23.

#6. There is a great sense of urgency to proceed with design and construction of the new national wind tunnels. European competitors of U.S. aircraft manufacturers have exploited the testing technology advantage they have gained over their U.S. counterparts. (See Section 4.2 of Reference 1, pages 13 - 15). This technology advantage is one element of the success of Airbus in continuing to gain transport aircraft market share, at the expense of U.S. ;manufacturers. Airbus has surpassed McDonnell Douglas in this market, and is poised to surpass Boeing, too.

The current study is not delaying the new wind tunnels, but is necessary precursor. However, the program must proceed promptly and without interruption. Opportunities to improve the overall schedule for completion should be developed, explored, and implemented, if feasible. The schedule should be limited only by the technical pace required to design, fabricate, calibrate, and commission these essential facilities.

#7. Siting must be based on fully meeting the site requirements at the minimum life cycle costs. If existing infrastructure can meet the site requirements with less cost, then it should be given a high priority.
For additional information See Reference 1, paragraph 7.5a, page 22

#8. The principle roles of the U.S. government in the field of aeronautics are:

(1) Conducting research and development activities to develop basic aeronautics technology in fields such as aerodynamics, propulsion, structures, avionics, and the like.

(2) Providing large scale and expensive laboratories for the use of the U.S. aeronautics industry. Such facilities are typically too expensive for individual companies to build. They are not typically used full-time by any individual company. Shared use by a number of companies results in more efficient use of the laboratories.

(3) Providing regulations in areas such as safety and environmental impact.

A comparison of U.S. and European wind tunnel development is provided in Section 4.2 of Reference 1, pages 13-15.

#9. The current organizations for NASA, FAA and DoD are effective. NASA focuses on basic R&D technology development. The FAA focuses on safety issues, and calls on NASA for technical support as needed. DoD takes full advantage of technical developments at NASA, but also has some technology development internally. The latter is not a duplication of NASA work, but is focused sharply on military applications. Similarly, NASA also has aeronautics developments that are focused on commercial transports and general aviation, primarily the former.

Thus, these three elements of government aeronautics have different but complimentary roles and missions

#10. The current study is focused on establishing requirements for the new wind tunnels, development and refinement of initial concepts, enhancement of preliminary cost estimates, establishment of the schedule, and the formation of a Limited Liability Corporation (LLC). Both industry and government will support the program and the LLC with personnel and financially.

The first phase of the study will be completed in July 1995, and is fully funded. The information provided by the study in the areas listed above will permit initiation of preliminary design for two wind tunnels (one subsonic and the other transonic) and related support facilities required for operation. The study team is focused clearly on providing the best facilities for the target budget of $2.28 billion. Additional funding for phases 2A and 2B has recently been approved, and is included in the budget for follow-on years. This will carry the program through preliminary design, into detailed design, and will cover ordering of long-lead items.

#11. The NWTC should be a national initiative, primarily supported by NASA, DoD and the aerospace industry. Many other groups like the FAA, the academic community and the small aircraft community will also be supportive. The prime agencies and the industry should continue to develop a funding plan like the "Unitary Act", which covered NASA and DoD, with some funding help from industry. The DoD is currently developing an advocacy program.

For additional information, see Sections 6.1 - 6.5 (pages 19 and 20) and 7.4 and 7.5 (pages 21 and 22) of Reference 1.

#12 There are no viable alternatives to the two new wind tunnel facilities. Several options for upgrades of existing facilities have been and are being explored, but none provide the Reynolds number and productivity of the proposed facilities.

In addition, see Reference 1, sections 7.2, 7.3, and 7.4 (pages 21 & 22).

#13 While commercial aircraft manufacturing is one of the prime beneficiaries, basic infrastructure like wind tunnels have traditionally been provided by government funding, with industry providing funding for the operational costs of the testing they do, especially when there is an equivalent national security requirement for DoD developments. See paragraph

#14 See Reference 1, sections 7.1 through 7.5, pages 21 & 22.

Responses To Questions Submitted For The Record To Dr. Arthur Charo For The Hearing Of March 16, 1995

Questions Submitted By The Hon. F. James Sensenbrenner

1. Is Mission to Planet Earth focusing on the most pressing scientific questions?

In response to budget cuts and subsequent restructuring, NASA has narrowed the scientific focus of Mission to Planet Earth and the Earth Observing System to those issues associated with global climate change. NASA's decision to make the determination of the extent, causes, and regional consequences of climate change its first priority is in accord with the recommendations established by the U.S. Global Change Research Program (USGCRP). It also follows the recommendations of international advisory groups concerned with global change (e.g., the Intergovernmental Panel on Climate Change).

As noted in written testimony, in 1993 OTA convened a two-day workshop to examine EOS and global change research programs. The workshop brought together some of the nation's leading atmospheric chemists, public policy experts, and global change researchers, as well as officials, laboratory heads, and scientists from NASA, NSF, DOE, and NOAA. This group generally believed that EOS (and, by extension, MTPE and USGCRP) science priorities were ordered correctly. However, several participants were concerned that a narrow focus on climate change would hinder study of equally important global change phenomena and leave the nation more vulnerable to scientific surprises. OTA also concluded that an effective program should provide mechanisms to allow for redirection, substitution, or termination of program elements in light of new discoveries, advances in technology, and changing needs of policymakers (such as the advances in technology, and changing needs of policymakers (such as the belated discovery of the polar ozone holes). Participants also believed greater attention should be given to potential impacts of climate change and to possible mitigation and adaptation strategies.

In addition, there was sharp disagreement over whether the EOS program was structured optimally to accomplish its stated objective of acquiring a detailed understanding of climate and related global change processes. This sentiment was present in discussions on the need for greater attention to in-situ measurements and detailed studies of the mechanisms underlying global change phenomena. It also appeared in discussions on whether EOS funding would be sustainable and whether a small core of key instruments should be developed for flight on smaller, less expensive satellites. Despite disagreement on these issues, there was general agreement that the value of satellite measurements would be greatly enhanced by greater attention to comparatively inexpensive "ground-truth" and correlative measurements.

Underlying the debate over the direction and scope of MTPE and EOS is the fundamental question of whether a "better" program could have been designed in the early 1990s had it been known that budget ceilings through FY 2000 would fall 60 percent by 1995. The scientists and NASA officials who developed EOS could not have the benefit of hindsight when the program was designed. They have now restructured the program to focus on climate change in a way that they believe maximizes scientific return. Furthermore, they note that plans to acquire a set of 24 key data sets have remained stable during repeated downsizing.

NASA officials told OTA that they recognize the critical importance of acquiring data on global change phenomena other than climate change, including land cover change, and changes in ecosystems and biodiversity. They also believe incorporation of the Landsat program into the MTPE and MTPE's terrestrial ecology program will help address these issues. In addition, they point to their involvement in developing the higher resolution "Lewis and Clark" demonstration spacecraft as evidence of their commitment to addressing global change issues other than climate.

2. Does Mission to Planet Earth cover enough time to actually produce accurate indications of climate change? Will the data that is produced from the MTPE actually be able to differentiate between climate change that is caused by humans as opposed to natural variability? Will we be able to make regional predictions by 2017?

Monitoring, understanding, and predicting the effects of global climate change will require both short-term detailed "process" studies to elucidate the mechanisms underlying climate change phenomena and a long-term (decadal timescale) commitment to a comprehensive observing and modeling program. NASA has designed EOS to provide 15 or more years of continuous high-quality (calibrated) data sets related to research priorities of the USGCRP. To achieve 15-year data sets, the principal EOS polar platforms, which have a design life of 5 or more years, would be flown three times.

Most scientists believe an observation period of 15 years is long enough to observe the effects of climate change resulting from the sunspot cycle (11 years), several El Nino events, and eruptions of several major volcanoes. It should also be possible to observe some effects of deforestation and other large-scale environmental changes. Scientists are less certain whether 15 years is long enough to distinguish unambiguously the effects of increasing concentrations of greenhouse gases on Earth's temperature from natural fluctuations. Fifteen years is certainly not sufficient for ecological studies of the health and migration of terrestrial systems. These studies will require continuous records of perhaps 20-50 years.

The duration of the EOS program is likely to be long enough to distinguish *some* anthropogenic effects from natural effects, albeit perhaps only on a coarse scale. NASA expects that by 2017, it should be possible to characterize climate change and forecast long-term changes. NASA also expects to be able to make accurate assessments of sea-level changes, and enable integrated regional assessments of land and water resources and use.

Currently, NASA's Topex/Poseidon ocean monitoring satellite is providing critical measurements related to predicting the onset and severity of El Nino. Over the course of the EOS program, scientists should acquire long time-series of data from Topex/Poseidon and its successors (assuming they are funded and orbit successfully). These data, and data from other EOS satellites and complementary earth science programs, should allow refinements in the predictions of El Nino and other global change effects.

However, there is great uncertainty as to when numerical models will be able to reliably predict the regional effects of global change. Although it is possible to make reasonably informed predictions on increases in computational capabilities, it is difficult to predict when future theoretical models will be able to capture the myriad of coupled land, ocean, and atmospheric processes in sufficient detail to enable regional predictions. In part this difficulty stems from not having a good enough observational data base to test models and ensure that important elements are not missing.

Achieving the long-term goal of making useful regional predictions of global change effects will require a commitment to a balanced program of comparatively short-term, science-driven studies of the mechanisms underlying global change, and a longer-term commitment to monitoring indices of global change. In turn, this will require a balanced program that utilizes space-based, in-situ, and ground-based measurement systems.

3. EOS is projected to cost tens of billions of dollars over its approximately 30-year life (program initiated in 1991 and will extend to 2017-2020). How should progress and performance of the program be measured?

The timetable for governmental decisions is driven by the yearly budget cycle and an election cycle that ranges between 2 and 6 years. Not surprisingly, policymakers funding global change research often have a shorter time horizon for "answers" than researchers. This disparity leads to tension between government officials who are required to formulate annual budgets and make immediate decisions, and the scientific community, whose long-term research depends on continuous and reliable funding. When scientists cannot answer the questions of policymakers in one or even a few years, they find it more difficult to "sell" a program as relevant to policy needs. The result may be annual budget fluctuations or rapidly shifting priorities--both of which are detrimental to the development of a sound scientific program.

One of the more recent attempts to bridge the gap between science research and the policy process in USGCRP was an introduction of scientific "milestones" or goals that can be easily identified by policymakers to help keep track of progress and program direction. However, this approach has had only limited success. According to one workshop participant at OTA's 1993 workshop, "the [scientific] community hasn't really bought off on those milestones .... Unless the community . . . feel[s] a sense of ownership of that list, it is not only worthless, it is counterproductive." Within the USGCRP, there is now increased interest and funding for the development of new decision analysis tools and methodologies for integrating assessments of global change, its impacts, and potential response options. These may also help policymakers assess program progress. However, the difficulty of developing a systematic plan that has measurable milestones or other objectives is likely to remain to the extent that instability in funding makes USGCRP and Mission to Planet Earth "budget-driven," and not "science-driven" programs.

4. Program Balance: Is there a proper balance in the program among ground-, ocean-, air-, and satellite-based measurements?

Mission to Planet Earth is embedded in a larger national and international effort to understand and predict the consequences of global change. Therefore, OTA believes the issue of program balance should be addressed across the USGCRP, and not just Mission to Planet Earth and EOS. The key agencies funding global change research are NASA, NSF, DOE, and NOAA. During the Bush Administration, NASA was assigned the lead role in enabling global observations from space. As OTA noted in its background paper *Global Change Research and*

NASA's Earth Observing System, valid concerns over the lack of attention to ground- and air-based measurements in USGCRP are partially attributable to lack of non-NASA agency support.

On the other hand, in a fiscal environment where agency budgets increase by only small percentages, or even decrease in real terms, it may not be practical to rely on agencies outside NASA for large infusions of new money for global change research. Furthermore, it is logical to draw on NASA's expertise in aeronautics to enable airborne measurements in support of the USGCRP. For example, OTA's 1993 study highlighted the need for greater attention to the development of unpiloted air vehicles and lightweight instrumentation for low-cost in-situ measurements of the upper atmosphere. Since the publication of this report, NASA has, in fact, made such a commitment.

OTA believes that problems of program balance can be best addressed by having the executive branch develop a coherent multiagency strategy for civilian remote sensing, and by having Congress develop more effective methods to oversee and fund multiagency programs (see ch. 3 of OTA's *Civilian Satellite Remote Sensing: A Strategic Approach*). Absent such a strategy, balance within USGCRP programs is likely to continue to be a concern because of the overwhelming dominance of NASA funding in shaping the nation's global change research agenda.[1]

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[1] For example, the Department of Interior, which manages large tracts of lands that could be affected severely by climate change, requested a *decrease* in USGCRP funds for both FY 1993 and FY 1994. DOI's position reflects a stance common to most agencies participating in USGCRP--budgets are tight and climate change does not present an immediate management concern. Another dimension of the problem of funding an appropriate mix of satellite and non-satellite measurement programs is the historical attraction of Congress to space-based research. Federal agencies may correctly perceive that it is easier to get financial support for large, space-based projects than for other research.

5. Are there lessons to be learned from NAPAP (National Acid Precipitation Assessment Plan)? Has NASA taken this experience into account in planning MTPE?

Lessons Of NAPAP

Congress passed the Acid Precipitation Act in 1980, thereby establishing an interagency task force to plan and oversee a 10-year National Acid Precipitation Assessment Plan (NAPAP).[2] The purpose of NAPAP was to increase understanding of the causes and effects of acid precipitation through research, monitoring, and assessment activities. NAPAP was intended to be useful to policymakers--the program emphasized the timely development of science for use in decisionmaking.[3]

Although NAPAP succeeded in its research efforts, it did not provide policy relevant information in a timely manner. In its 1993 background paper, *Global Change Research and NASA's Earth Observing System,* OTA attributed much of this problem to the lack of sufficient attention to development of assessment methodologies.

Assessment and policy analysis research develops and uses quantitative methods to organize and communicate scientific and other information in ways that allow comparison of policy choices. These methods include decision analysis, benefit-cost analysis, risk analysis, and technology assessments. Although NAPAP eventually produced an integrated assessment in 1990, its lateness diminished its utility to policymakers formulating amendments to the Clean Air Act.[4] In addition, the effectiveness of the 1990 integrated assessment was limited as NAPAP officials either failed to execute, or underfunded, important ancillary assessments. This included, for example, an evaluation of the economic effects of acid deposition on crops, forests, fisheries, and recreational and aesthetic resources, and a determination of the implications of alternative policies.[5]

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[2] NOAA, USDA, and EPA jointly chaired the task force which also consisted of members from DOI, HHS, DOC, DOE, DOS, NASA, CEQ, NSF, and TVA, along with representatives of the Argonne, Brookhaven, Oak Ridge, and Pacific Northwest National Laboratories and four Presidential appointees.

[3] Oversight Review Board of the National Acid Precipitation Assessment Program, The Experience and Legacy of NAPAP, Report to the Joint Chairs Council of the Interagency Task Force on Acid Deposition, April 1991.

NAPAP and Mission to Planet Earth

As noted in *Global Change Research and NASA's Earth Observing System,* the insights gained from the experiences of NAPAP were not explicitly considered when designing the U.S. Global Change Research Program or its Mission to Planet Earth component--larger programs on both a temporal and spatial scale than NAPAP. Furthermore, OTA noted that the assessment methodologies component of USGCRP would benefit from greater attention and coordination with other activities. In the two years since the publication of OTA's background paper, officials in both programs have taken steps to develop better methods to communicate scientific results to policymakers. This has been particularly evident in the last budget cycle.

In FY 1995, the USGCRP markedly increased its support for programs designed to develop tools for assessing policies and options, especially in the area of "integrated assessment methods" (IAMs). IAMs combine research results from natural, social, and policy sciences in way that policymakers can use to evaluate likely results of different research investments (e.g., the likely outcome and cost of pursuing different strategies to reduce greenhouse gas emissions).[6]

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[4] U.S. Congress, Government Accounting Office, *Acid Rain: Delays and Management Changes in the Federal Research Program,* GAO/RCED-87-89 (Washington, DC: U.S. General Accounting Office, April 1987).

[5] Ibid.

NASA is relying on EOSDIS as its primary means by which scientists, educators, and the general public will be able to make use of the data collected by MTPE and other programs. Because EOSDIS is still in its earliest stages, it is too early to know if it will succeed in its stated objective of developing tools to enable this diverse group to have fast, flexible, and easy access to global data sets. It is noteworthy, however, that MTPE officials (and those of the USGCRP) have stated that they are aware of the problems suffered by NAPAP. Providing policy-relevant information on a timescale commensurate with the needs of decisonmakers is a key objective of both programs.

6. Why is EOSDIS critical to the overall success of MTPE and to the entire U.S. Global Change Research Program? If EOSDIS fails what happens to the rest of the program?

The EOS Data and Information System is the key element in NASA's plan to enable the anticipated massive amounts of MPTE satellite and research data to be turned into useful information by project investigators, scientists, educators, and the public. EOSDIS will store and distribute MTPE data, as well as develop interpretative tools and high-level data products. EOSDIS is part of GCDIS, the global change data and information system that is being developed as part of the USGCRP. Like EOSDIS, GCDIS is being designed to combine data from various disciplines and disparate sources and distribute synthesized data products to investigators worldwide. Delays in the development of EOSDIS data products, or difficulties in data storage and distribution, would therefore adversely affect all of U.S. global change research efforts.

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[6] See Committee on Environment and Natural Resources Research (CENR), *Our Changing Planet: The FY 1995 U.S. Global Change Research Program,* (Washington, DC: CENR, Executive Office of the President, 1994), pp. 82-84.

Questions Submitted For The Record By The Hon. Ralph M. Hall

1. Dr. Teller provided testimony on the potential deployment and utilization of a constellation of several hundred small satellites in near-Earth space to provide early military warning, weather prediction, and environmental monitoring.

a. Has the feasibility and cost-effectiveness of such an approach to meet the scientific requirements of Mission to Planet Earth been assessed by OTA or by any other independent review panels? If so, what have been the results of those reviews?

b. Would it be possible to implement such an approach on the current EOS timetable? If not, why not? What would the cost of such a system be?

To OTA's knowledge, there has never been a detailed analysis of Dr. Teller's proposals. In part, this is because proposals to use constellations of mini- or small-satellites for missions traditionally accomplished with fewer numbers of larger satellites have never been developed in sufficient detail to permit such an examination.

Dr. Teller's proposal appears to build on the "Brilliant Eyes" concept that was proposed, but never developed, for space-based surveillance in the Strategic Defense Initiative. OTA received briefings about satellite design and satellite technology from numerous sources at NASA, NOAA, DOE, DoD, and at many of the DOE national laboratories, as part of its study *The Future of Remote Sensing From Space: Civilian Satellite Systems and Applications*. We also received briefings from contractors involved in both large and small satellite development for civilian and military use. Among the advanced technology items shown to OTA were miniature star trackers, compact optical systems, small mechanical cryogenic coolers (e.g., to cool the focal plane of long-wavelength infrared detector arrays), and a variety of small and lightweight electronic components and high-capacity computers. In addition, we were informed of progress in developing flight-worthy lightweight materials and structures, solid-state data recorders, and other satellite components.

Advances in technology show great promise in reducing the size and weight of current systems. In fact, some have already been used by DoD to develop the highly successful Clementine mission that mapped the lunar surface. Advanced technologies are also enabling the development of comparatively inexpensive commercial remote sensing satellites (however, they are being designed for niche markets and will not have the capabilities present in Landsat). In addition, NASA is pursuing small satellite technology demonstration programs and is studying the potential to use small satellite technology in the second and third phases of EOS.

However, to understand how Earth's environment might be changing and to distinguish between natural and human influences requires space-based systems capable of making repeated, *calibrated* observations over long periods. For many types of observations (such as those of the Earth's land surface) it also requires sun-synchronous orbits, which allow sensors to view the Earth at the same time of day and thereby remove a key source of ambiguity in the interpretation of reflectance signals. The development of small and lightweight instrumentation should be viewed as only a necessary first step in developing a capability useful for global change research.

The discussion thus far has touched on some of the issues associated with developing constellations of satellites for environmental monitoring. However, Dr. Teller is proposing an even more ambitious system--one that would simultaneously provide environmental monitoring, weather prediction, and military surveillance. In addition to developing miniature sensors with the requisite calibration and spatial, spectral, and radiometric resolutions to be useful for environmental monitoring, such a system would have formidable additional technical requirements dictated by the unique needs of NOAA and DoD for high-resolution atmospheric soundings and high-resolution imagery. In addition, there would be a host of organizational problems related to differing agency views and practices regarding resource allocation, instrument design, satellite control, and data processing and dissemination.[7]

With regard to the questions in part b:

OTA does not believe it would be possible to implement Dr. Teller's proposal on the EOS timetable, even if there were not numerous technical uncertainties. The first EOS spacecraft and suite of instruments are already well into the development phase, and the rest of those in the first series are well into the design phase. Dr. Teller's proposals could be investigated for latter parts of the EOS series; in fact, NASA is examining various new options for this series, including working with industry to better incorporate technological advancements expected over the next decade. NASA officials also told OTA they are examining the possibility of new partnerships with industry where there are significant commercial remote sensing opportunities.

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[7] An analysis of the difficulties in managing a combined NOAA and DoD operational weather satellite program gives an indication of the magnitude of this challenge. See chapter 3 of OTA's *Civilian Satellite Remote Sensing: A Strategic Approach*.

OTA is not able to characterize the cost estimates for this proposal for the reasons outlined above. It should be recognized, however, that Dr. Teller's estimate of $1 billion per year as the cost to install and maintain 1,000 thousand small satellites with a 5-year lifetime is equivalent to an average cost of $5 million per satellite. This would be a remarkable achievement considering that current "small" satellites are defined as those costing $100 million or less (including launch costs). Finally, we note that while Dr. Teller's vision may not be practical in the near-term, it does capture the importance of collaboration across the federal agencies and the importance of capitalizing on the expertise resident outside NASA, especially in the national laboratories and the private sector.

2. What would be the impact of additional cuts to the Mission to Planet Earth program on the ability to meet scientific research objectives?

NASA officials told OTA that successive budget-driven restructurings since 1990 have already left the EOS program with a minimal capability needed to make the measurement set established by the science community as required for the study of global climate change. OTA believes that additional cuts to MTPE and EOS would likely result in some combination of deferral or cancellation of planned EOS flights, cutbacks in EOSDIS, and further reductions in already pared research and analysis activities (R&A). The immediate result of further budget cuts would likely be a delay in EOS-AM and EOS-PM. Depending on the size of the cuts, it might be necessary to rethink the entire concept of EOS.[8]

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[8] In practical terms, EOS-AM may already be too far into development to be stopped, even if one were willing to accept the loss of anticipated data. EOS-PM is not as far into development; however, cancellation of PM would affect plans for a "converged" NOAA-DoD weather monitoring system. Thus, changes in EOS budget are most likely to impact successors in the AM and PM series.

At OTA's 1993 workshop on global change research and EOS, experts disagreed when asked if a restructured EOS would necessarily compromise science objectives. Those who believed that the program would benefit from further attention to in-situ and ground-based process studies (and who assumed that funds saved from a restructuring would indeed be transferred to these programs) welcomed wholesale restructuring, as did those who advocated greater attention and funding for small satellite missions. Other participants and NASA officials disagreed, arguing, in effect, that the science that might be gained by restructuring was less important than the delay and instability that would surely accompany a less than evolutionary approach to change. In more recent briefings to OTA, NASA officials also noted that they are already considering substantial changes in the second and third phases of EOS.

OTA's study did not resolve this dispute--even if it were not beyond the scope of our study, it would have required weeks of analysis by our advisory group, and not the two days we had for discussion. OTA did conclude, however, that a successful global change research program--that is, one that might achieve such long-term goals as being able to make accurate predictions of the onset and severity of El Nino, or changes in midwest precipitation patterns--should have a space-based component balanced by a vigorous, science-driven program of in-situ and ground-based measurements. We also concluded that an effective program should provide mechanisms to allow for redirection, substitution, or termination of program elements in light of new discoveries, advances in technology, and changing needs of policymakers. Developing these mechanisms will not be easy. As one of OTA's advisers remarked, "Crucifying a program is the easy part; it's the resurrection part that requires divine intervention, and that's a little harder to arrange."

3. Given the current state of technology and the status of Low Earth Orbit (LEO) communication satellite constellations, how feasible would it be over the near term to carry out the space-based segment of Mission to Planet Earth by means of sensors mounted on such commercial satellites? What do you see as the main issues with such an approach?

OTA does not believe that the space-based segment of MTPE can be accomplished in the near-term by mounting sensors on commercial satellites. For example, the proposed Iridium network of communication satellites will not be situated in sun-synchronous orbits and they have little or no extra capacity to carry sensors for global change research. Furthermore, as noted in our response to Dr. Teller's proposal, proposals to accomplish global change research programs with constellations of mini-satellites are ill-defined and make optimistic assumptions about technology that has either not been developed or is still immature.

Scientists are still in the research phase of understanding the climate system and other aspects of global change. Even if it were possible to create a constellation of low-Earth orbit mini environmental monitoring satellites, there is no guarantee that such satellites would monitor the correct set of variables with the requisite accuracy. In fact, this is one of NASA's principal arguments for the necessity of developing and orbiting research satellites of the kind envisioned for EOS.

OTA does believe that future commercial imaging systems or communication systems in low Earth orbit, as well as communication satellites in geostationary orbit, could become important elements of a space-based global environmental monitoring system, **but only if they were designed *a priori* to do so.** In principal, the cost-efficiencies possible with current multi-instrument satellites would be possible with these multiuse satellites. However, there are both technical[9] and organizational challenges with this approach. In OTA's view, this is another example of the need to develop a national strategy for environmental remote sensing that draws on the expertise and financial resources resident in federal agencies, national laboratories, academia, and the private sector.

4. As Mission to Planet Earth has been restructured to accommodate budget reductions, some of the original capabilities for the system have had to be descoped. How has NASA used international cooperation to mitigate the impact of these budget decisions?

As I noted in my response at the hearing to the question from Rep. Weldon, NASA has responded to program downsizing in part by increasing its reliance on international partners. There are both risks and benefits to this approach, which OTA discusses in its publications (see, for example, chapter 3 and chapter 4 of *Civilian Satellite Remote Sensing: A Strategic Approach*).

International cooperation has always been a hallmark of MTPE, with foreign country instruments on U.S. spacecraft, U.S. instruments on foreign country spacecraft, and extensive international collaboration in research. The recent "rebaselining" of the program as a result of the FY 95 budget process has led NASA to expand international participation. NASA now plans to fly the Stratospheric Aerosol and Gas Experiment (SAGE III) instrument on a Russian METEOR spacecraft in 1998 and the SeaWinds instrument on the Japanese ADEOS-2 in 1999. NASA is also negotiating with Canada on a cooperative mission for the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) instrument, and is also exploring the possibility of flying the Cloud and Earth Radiance Experiment System (CERES) on a follow-on Tropical Rainfall Measuring Mission (TRMM) with Japan in 2000.

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[9] The technical challenges include such obvious questions as whether communication sensors and, say, imaging sensors, can share a common communications downlink and ground processing system. There are also include numerous issues related to the integration of sensors that must be compatible in terms of such parameters as pointing and stability, power, and cooling requirements.

GAO
United States
General Accounting Office
Washington, D.C. 20548

Accounting and Information
Management Division

April 11, 1995

The Honorable F. James Sensenbrenner, Jr.
Chairman, Subcommittee on Space and
Aeronautics,
Committee on Science
United States House of Representatives

On March 16, 1995, we testified before the Subcommittee on the National Aeronautics and Space Administration's (NASA) development strategy for the Earth Observing System Data and Information System (EOSDIS). In response to your questions, we are providing the following answers as a supplement to our testimony.

1. *Is it possible for EOSDIS functions to be provided by the private sector?*

   To date, our review of EOSDIS has not specifically addressed the issue of whether all or some part of EOSDIS could be managed by the private sector. Data from several planned EOS instruments could have value to commercial users involved in activities such as oil and mineral exploration, forest management, and geological mapping. Given this market potential, it may be possible to turn over some data distribution functions of EOSDIS to the private sector. However, substantial savings might not be realized if commercial demand does not develop as expected. In addition, scientific research could be impeded if researchers find that EOSDIS data is too costly to obtain and analyze.

   If EOSDIS is turned over to the private sector, it will need to be done in a way that preserves close and flexible interaction with the global change research community. The system will face continuously evolving data processing and management needs as researchers analyze and react to incoming data and refine and improve their data processing algorithms. The system will need to remain open-ended and capable of evolving to meet users' needs.

2. *To what degree will the Internet be used in conjunction with EOSDIS?*

   Already, the early prototype Version 0 of EOSDIS is linked to the Internet. Each of the EOSDIS Distributed Active Archive Centers (DAACs) has an easy-to-use graphical user interface that is accessible via the Internet. In some cases, Internet users can access the Version 0 system directly from these Internet interfaces. Although the core group of EOS principal investigators will have special dedicated connections to EOSDIS, it is expected that most users will access the system through the Internet.

The burgeoning growth of the Internet may represent a valuable opportunity for NASA to save system development costs associated with developing and maintaining user interface software by relying, wherever possible, on publicly available standards and products. However, some scientists worry that the Internet will not have the capacity to support transferring large amounts of data to scientists online. It is possible that the DAACs will have to ship data to at least some users on magnetic tape or CD-ROM, an activity that NASA has not planned for within the EOSDIS project.

3. *Why is EOSDIS critical to the overall success of Mission To Planet Earth (MTPE) and to the entire U.S. Global Change Research Program? If EOSDIS fails what happens to the rest of the program?*

EOSDIS is the critical link that will allow the raw data collected by the EOS satellites to be turned into meaningful information about global change. Without the extensive processing, archiving, and distribution functions that EOSDIS will perform, the data collected by EOS' satellite-based instruments will be of little value.

The streams of data produced by individual instruments generally represent series of isolated measurements that may have little meaning in and of themselves. The messages hidden in those data streams tend to emerge only after the data has been through a substantial amount of computer processing and packaging. First, an extensive, iterative process is usually required to ensure that a set of data represents reliable physical measurements and has not been distorted in some way due to the practical circumstances under which the readings were taken. Second, the data from one instrument may tell only a small part of the story of global change. Deeper meaning is likely to emerge only after that data is compared or combined with data from other space-based or ground-based measurements that have been made over long periods of time. EOSDIS will be the mechanism that facilitates this intensive data analysis activity. If EOSDIS fails to adequately support this activity, scientists and policymakers will be unable to extract important information about global change from the flood of data amassed by the EOS satellites.

4. ***Vulnerability:* What happens if there is a breakdown in the system so that storage, processing, or distribution of the data is compromised?**

As with any system, a variety of "breakdowns" of the system would be possible. The least serious would be temporary malfunctions within the storage, processing, or distribution segments. Such problems might temporarily delay some research activities but would not lead to any permanent loss, since all critical data will be stored in backup archives. More serious would be long-term, endemic problems, such as an inability for the processing system to keep up with the incoming data flow, or an inability of the distribution system to provide data to researchers in an efficient, timely fashion. EOSDIS risks facing such problems to the extent that the needs of its users are still not well known. The effect of such problems could be to discourage researchers from using EOSDIS, which, in turn, could limit the scientific return on the overall investment made in the EOS program. However, if EOSDIS is developed in a flexible, incremental fashion, it should be better able to adapt to changing user needs and avoid long-term system shortfalls.

5. ***Cost Estimates:* NASA has not produced cost estimates for MTPE beyond the year 2000. Does GAO have a sense as to whether the EOSDIS budget levels off at the year 2000 and is maintained at that level with inflationary increases? Or is it reasonable to assume that EOSDIS will ramp up from the level in 2000?**

NASA's internal budget information indicates that EOSDIS costs will level out after 2000 with inflationary increases. The agency is forecasting a budget of $372 million in 2001, with annual increases of 4 percent, due to inflation, after that. It is, of course, very difficult to validate such a forecast. However, it is worth noting that NASA does not envision any decline in the outyears from its investment in 2001, which is a peak year. This suggests that ongoing development work will be needed to update and "evolve" EOSDIS on an annual basis. The more ambitious the initial system is, the greater the likely outyear costs to keep the system updated and operational.

6. ***DAACs:* In your estimation are all the DAACs (Distributed Active Archive Centers) essential to the mission?**

Based on ideas suggested by the Independent Architecture Studies commissioned by NASA, it will not be essential to have full data processing, archiving, and distribution activities at 8 DAACs as currently envisioned. Consolidation of data processing activities in particular may be possible, although we have not had an opportunity to assess whether any cost savings would accrue. It is important to note, however, that the DAACs serve a vital role as representatives of the scientific user community and are the closest links that NASA has to the researchers who will be using EOSDIS. The DAACs clearly have a useful role in serving as user focal points, even if they may not need to take the form of 8 large data processing centers.

NASA is also supporting a ninth data center, the Socioeconomic Data and Applications Center, which will specialize in analyzing the human impact of global change. The center, operated by the Consortium for International Earth Sciences Information Network (CIESIN), will not house earth science data. We currently have a separate review ongoing to assess CIESIN's role in the EOS program, and we will report our results back to you as soon as our work is complete.

7. *__Advanced Technologies__: Are available information system technologies sufficiently advanced today to support the unprecedented size and complexity of EOSDIS when it is completed?*

As discussed in our testimony, critical software technologies needed to ultimately make EOSDIS successful are still beyond the state of the art. New technologies will be needed to handle the vast amounts of science data that EOSDIS is expected to contain. For example, current database search techniques, which were generally designed to meet the needs of transaction-based business applications, are inadequate to support the work of interdisciplinary scientists. Users of current systems find they must order and receive data only in large chunks, which they must then sort through manually to retrieve the data that is of real interest to them. Given this situation, NASA needs a more concerted program of research and prototyping activities to narrow the gap between scientists' needs and EOSDIS capabilities.

8. *In your testimony, you state that Hughes is spending as much as $7.5 million a month on development work for EOSDIS. And that the focus is on large-scale development instead of research and prototyping.*

a. *What is the ultimate impact of such a focus?*

If NASA continues to pursue this approach, it risks building a system, at great expense, that will not provide significant advances in scientific data handling over currently operational systems. Such a system would likely fail in its objective to facilitate new ways of assessing global change by studying the earth as a single, integrated system.

b. *Have you been given any indications that NASA intends to re-examine the development process in EOSDIS?*

NASA has not indicated to us that it is considering any significant changes in its development strategy.

c. *Why is it so important that EOSDIS development give priority to research and prototyping?*

As discussed in our answer to Question 7, research and prototyping are critical because proven technology does not yet exist to carry out all the functions that will be needed in a successful EOSDIS. Research efforts must be supported so that potential solutions to these problems can be fully explored. Once a potentially valuable new technology has been identified, prototyping is critical to test the concept, not just to see if it works from a technical perspective but also to explore how satisfying it is to users. If the EOSDIS program limits these activities, it limits its ability to pursue and adopt new technologies within EOSDIS.

This issue can also be considered from the perspective of its potential for enhancing U.S. technological competitiveness. EOSDIS is a major effort that must push the state of the art to meet real scientific needs. By concentrating on addressing these technological issues, NASA can stimulate development of new technologies that could potentially have wide-ranging benefits for the U.S. economy.

d. *What kind of system will result if we spend the bulk of the money on merely implementing existing technology?*

In all likelihood, the kind of system resulting from this approach would have limited utility. In the immediate near term, it might be successful in meeting the needs of the EOS principal investigators as they conduct the experiments that they have already planned. In the longer term, the system might be of very little value to other scientists who would want to use the great store of data in EOSDIS to answer new questions. The system would likely be least useful in helping to answer the broadest questions about global change, because such questions would require correlating and analyzing large amounts of diverse data.

We appreciate the opportunity to testify before the Subcommittee and to provide this information for the record. If you have any further questions, please call me at (202) 512-6240.

Jack L. Brock, Jr.
Director, Information Resources Management,
National Security and International Affairs

Questions submitted for the Record from Dr. Teller

QUESTIONS AND ANSWERS

1. Is mission to Planet Earth focusing on the most pressing scientific questions?

The pressing questions are military intelligence, short-term weather prediction and observing the presence and immediate effects of pollutants. By contrast EOS emphasizes long-term effects where predictions are harder and more uncertain.

2. What are the advantages of using small satellites? How far have modern electronics, computers and spacecraft component technologies developed? Are we to the point that small satellites could be used for the MTPE program?

Progress in electronics and particularly in computers are outpacing their applications. In computers, twofold improvements can be conservatively estimated every five years amounting to almost a hundredfold improvement in thirty years. Small satellites available to carry small packages practically at a moment's notice are needed to take full advantage of the development of the instruments.

A further advantage in smaller less expensive satellites is that mistakes will not be too costly. It is not unusual to learn more from our mistakes, provided that they are not too expensive so that we can afford them.

3. You seem to be advocating many different uses for these satellites, not just an Earth-observing function for the MTPE program. Would it be possible to combine this Earth-observing function with an asteroid detection function?

Asteroid detection from near-Earth orbits has a twofold advantage: One is the 24 hr. availability of our instruments for actual observation; the other is the great improvement in detailed intensity measurements. For instance, asteroids are known to rotate and change their intensity within a short period. Accurate observation of these intensity changes could give most important data on the nature of asteroids.

4. Will the current EOS program result in the improvement of models to the point where policy makers can rely on predictions for making far-reaching decisions? When will policy makers be able to rely on climate model results?

In the planning of research it is of particular importance to ask the right questions and, indeed, ask the questions to which varied answers can be found. On short-term weather predictions, excellent answers might become available in considerably less than ten years. On the climate change, answers may take much longer for two reasons: One is the unavailability of detailed expermental verification; the other is the dependence of long-term changes on many factors including those not due to man's actions. In spite of great efforts, we still do not know what caused the Ice Ages. Nevertheless, I hope that real progress can be made on the climate model in one hundred years. Results on a considerably shorter time scale would become practical if you would engage in purposeful modifications of the climate. It is of course highly doubtful to what extent this program would be permissible and justifiable.

5. What happens if rides do not materialize for instruments slated for "Flights of Opportunity?" How will such a data gap affect the whole program?

The question would be justified if instruments would be the bottleneck. In actual fact, the bottleneck is almost always the availability of flights. The instruments will, as a general rule, be available.

6. Does Mission-to-Planet-Earth cover enough time to actually produce accurate indications of climate change? Will the data that is produced from the MTPE actually be able to differentiate between climate change that is caused by humans as opposed to natural variability? Will we be able to make regional predictions by 2017?

As is seen from my earlier answers, I tend to answer Question 6, in regard to all its details, in a negative way.

7. EOS is projected to cost tens of billions of dollars over its approximately 30-year life (program initiated in 1991 and will extend to 2017-2020). How should the progress and performance of the program be measured?

Progress is to be measured by practical results. In particular, in regard to short-term weather predictions, progress may be so great that private enterprise might take over the program of predictions and of selling the predictions.

8. Program Balance. Is there a proper balance in the program among ground-, ocean-, air- and satellite-based measurements?

For instance, an argument can be made that highly efficient lasers could be used in considerable numbers on the ground with satellites being applied to measure the penetrating or scattering laser beams. Satellites also could be used for the operation of unmanned stations on

Earth, for instance, stations adrift in the oceans.

9. OTA's report, "Remote Sensing from Space" states that increased cooperation with labs such as Lawrence Livermore would be useful because of the labs' experience in developing next-generation sensors and spacecraft. Is there any indication that NASA is reaching out to Lawrence Livermore to incorporate these technologies into the MTPE program?

Laboratories, including Lawrence Livermore, could be used in many cases with great advantage. This is particularly true because all good ideas are not apt to come from a single source.

Panel V

1. Which government agency conceived, developed, and implemented the Clementine program that so successfully demonstrated the concept of "faster, cheaper, better?"

Clementine was conceived by Lowell Wood and Stewart Nozette from Lawrence Livermore National Laboratory and Col. Peter Warden, SDIO/USAF.

The development and implementation was mainly carried out by SDIO with the strong cooperation of Naval Research Laboratory & Lawrence Livermore National Laboratory.

2. What was NASA's contribution to the Clementine program?

NASA was most helpful and effective in supporting the committee and the analysis of the Clementine data. NASA also gave support by the deep space network for communications.

3. What technology contributions can the Departments of Defense and Energy make to the Mission-to-Planet-Earth?

The Department of Defense has great experience with satellites. The Department of Energy has a specific job to find out more about proliferation. These point to ways in which these departments could contribute toward observations from satellites. But beyond these specific uses, NASA, the Department of Energy, the Department of Defense, the Naval Observation Laboratory and universities could all contribute in an effective manner.

Answers to Questions for the Record from the
Honorable F. James Sensenbrenner, Jr.
for the Hearing of March 16, 1995
Answered by Dr. Eric J. Barron

1. **Will the current EOS program result in the improvement of models to the point where policymakers can rely on predictions for making far-reaching decisions? When will policymakers be able to rely on climate model results?**

In October of 1994 the Forum on Global Change Modeling was held at the invitation of the Subcommittee on Global Change Research to produce a consensus document on the use of climate models in policy decisions. This report ranked from "virtually certain" to "uncertain" the major predictions of large scale global climate models. The consensus showed clearly that scientists have a high degree of confidence in being able to predict the range of global climate change due to human activities, but that the confidence drops considerably with increased level of detail (e.g. predictions by decade or by region). The report also detailed a large number of significant opportunities for improvement of climate model predictions. These include: (1) areas were sustained research will result in significant gains such as cloud-radiation-water vapor interactions, aerosol forcing, decade to century climate variability, land surface processes, variability affecting the frequency and intensity of extreme events (e.g. hurricanes), and ocean circulation and overturning, (2) improved spatial resolution to better represent regional scale features, (3) better representation of atmospheric boundary layer processes and vertical convection in the atmosphere, (4) improved observations of atmospheric water vapor, (5) improved linkages for coupling the atmosphere, oceans, and land surface, (6) more explicit representation of land surface processes, including vegetation, (7) greater emphasis on model intercomparisons, (8) improved reconstruction of paleoclimates to help assess model sensitivity and to improve model credibility, and (9) improved representation of atmospheric chemistry, vegetation and soils needed to improve prediction of radiative feedbacks and to allow calculation of the effects of other types of global environmental change. Research focussed on each of these nine major categories will improve model capability and improve our confidence in model predictions. With the exception of item 8, EOS observations and EOS investigators will make significant contributions in every area described above.

The incorporation of improved physical processes in climate models will certainly improve model capability, however this does not provide the full story of achieving reliable predictions of the future. An additional requirement is to understand and be able to specify the nature of the major factors which "force" climate change, including solar energy input, greenhouse gases, the distribution and character of atmospheric aerosols, and land cover changes. Without EOS, many of these forcing factors will not be monitored (e.g. solar variations, aerosols, land cover changes) and would remain areas of significant uncertainty and debate. EOS is essential to limit the uncertainties in climate model predictions due to knowledge of various climate forcing factors, as well as to improve the representation of physical processes in climate models. As a third factor, EOS will also provide important opportunities to validate climate models, thus increasing confidence in their predictions.

For these reasons, I have no hesitation, whatsoever, in stating that EOS will strongly enhance climate models and our confidence in their predictions. However, the question posed is far more complex in that the focal point is on when policymakers can rely on climate model results. Along with my scientific colleagues working on EOS, I am dedicated to addressing important scientific questions, rather than trying to guide policy. The point at which models can be used for making policy depends on far too many factors, including model capability, a host of cost-benefit issues, maintaining industrial productivity, and risk aversion. I am only competent to address the first of these issues (model capability). On this point, three issues are of importance: (1) the scientific community has confidence that future large-scale climate change due to human activities can be placed within a range, but the temporal and spatial details of these predictions are far less certain. Policies which address the details of climate model predictions, in my estimation, cannot be justified unless considerable vulnerabilities are present. (2) Significant progress in improving these predictions is likely to take a decade or more, and will only occur with concerted effort to monitor major climate variables and to improve the representation of physical processes in climate models. EOS is essential to this goal. (3) Even after a decade, models will be far from perfect. I expect that many predictions will move from a categorization of "uncertain" to "probable" or from "probable" to "very probable." Frankly, with some discoveries, we may actually decrease the level of confidence for a period of time. The reality is that scientists will continue to do their best to provide state-of-the-science predictions, based on the best data available, but there will continue to be uncertainties. Therefore, policymakers will see growing confidence in many elements of climate model predictions, but, in my opinion, will continue to have a difficult task of weighing the vulnerabilities to climate change. In short, there is no magic time at which point policymakers will be able to rely on every detail of climate model results. However, I also believe, that with increased research, we will see real contributions that help maintain national security and economic vitality as a direct result of EOS observations. I believe we will see tangible and measurable results from EOS and EOS investigators. In fact, much progress is already evident.

2. What happens if rides do not materialize for instruments slated for "Flights of Opportunity?" How will such a data gap affect the whole program?

Instruments slated as "Flights of Opportunity" reflect part of the history of large budget reductions in EOS over the last four years. We have a number of instruments for which the observations were deemed to be very important, but for which the budget or the status of international agreements did not allow a designated launch. We do not want to lose these observations and, therefore, the decision was to maintain capability while working hard to find an opportunity for flight. Four instruments fit within this category. ACRIM: ACRIM measures solar output and requires a series of continuous and overlapping observations. Loss of ACRIM would be significant because the degree to which solar variability may explain climate change is an issue of debate. Loss would also limit our ability to separate between natural and human-induced climate change. SOLSTICE: SOLSTICE measures UV radiation from the sun, which is significant for understanding ozone photochemistry and the energy budget of the Earth. These are significant issues. SAGE III: SAGE measures global profiles of aerosols, ozone, water and nitrous oxides. In the major budget reduction of last year, SAGE coverage was considered to be of significant importance and the project was asked to address all possible launches. CERES: CERES addresses clouds and the

Earth's radiation budget. These observations are critical to address cloud-climate feedback questions, which are frequently cited as one of the major uncertainties in climate models. CERES will be flown on other platforms, but the specific Flight of Opportunity (Tropical Rainfall Measurement Mission - follow on) gives coverage at a different time of day and synchronous measurements with precipitation. I would deem the loss of these measurements if a Flight of Opportunity does not materialize as significant.

3. Does Mission to Planet Earth cover enough time to actually produce accurate indications of climate change? Will the data that is produced from the MTPE actually be able to differentiate between climate change that is caused by humans as opposed to natural variability? Will we be able to make regional predictions by 2017?

Climate model predictions suggest significant climate changes will occur over the coming decades. Mission to Planet Earth is poised to observe the Earth system in order to assess these predictions and to monitor changes to our planet. If climate model predictions are correct, then the time span of these observations should be sufficient to increase substantially our knowledge of climate change. In other words, I believe that over the next 25 years we will have much more accurate indications of climate change. If the climate changes predicted by models are accurate, then MTPE will certainly detect these changes. However, model predictions may be in error for three major reasons: (1) inadequate incorporation of physical processes, (2) lack of knowledge of specific forcing factors or new, unanticipated climate forcing factors, and (3) surprises associated with natural climatic variability. This is the reason why the dual role of MTPE, monitoring and increased ability to predict climate change, is so essential. We can consider two scenarios. First, model predictions are relatively accurate, and the MTPE monitoring capabilities demonstrate or validate the predictions. Second, MTPE monitoring does not show evidence of climate change which matches model predictions. However, in this case, MTPE has also monitored other forcing factors (e.g. aerosols and solar output), has provided key observations required to improve physical processes (e.g. cloud-climate feedbacks) which are responsible for current model uncertainties, and has examined the coupled system which governs much of natural climate variability. MTPE, in this scenario, is essential to describe why the climate did or did not change as predicted. Certainly, this information serves to produce more accurate indications of climate change. Will more observations be required after 2017? I suspect that the information on the state of the atmosphere, oceans, vegetation and ice and snow will be come invaluable with regards to economic vitality and national security and that MTPE will prove useful well beyond just indications of climate change, and that there will be a growing demand for continued monitoring and improved predictions on the time scales of seasons, years and decades. The key challenge will be to provide these observations with inexpensive, timely satellites which are at the cutting edge of technology.

Each of the issues described above, improved models and monitoring the full climate system including the forcing factors will help us to differentiate between climate change that is caused by humans as opposed to natural variability. There is always the potential for surprises, and therefore, hard and fast statements that we will be able to fully differentiate the two are unwarranted. However, many of the areas of debate (e.g. the role of solar variability and the degree to which aerosols negate elements of global warming) will be considerably clarified if we have 25 years of observations of both climate variables and climate forcing factors.

There is already a growing effort to make regional predictions of climate change. With this effort as well as with continued advances in computer technology, with high resolution observations, and with directed research, I believe that we will see substantial improvements in regional predictions and far better assessments of our capabilities in this arena.

4. EOS is projected to cost tens of billions of dollars over its approximately 30-year life (program initiated in 1991 and will extend to 2017-2020). How should the progress and performance of the program be measured?

I believe that progress and performance of the program should be measured in four ways: (1) Evaluation of the breadth and depth of the scientific output of EOS and the degree to which this scientific output addresses the critical scientific questions which limit our current knowledge of climate and climate change, changes in atmospheric chemistry and changes in ecosystems. (2) Determination of whether there is demonstrated progress in improving model predictions. (3) Determination of whether there is demonstrated progress in separating natural variability from human-induced climate change. (4) Evaluation of whether MTPE is recognized, beyond its family of scientists, for its value to national security and economic vitality because of its importance in assessing and predicting changes in weather, climate, ecosystems, agriculture, and water resources.

Answers to Questions for the Record from the
Honorable Ralph M. Hall
for the Hearing of March 16, 1995
Answered by Dr. Eric J. Barron

1. The testimony provided by the GAO expressed concern that "NASA still has not given adequate attention to EOSDIS users, their expectations, or their needs." How has the planning for EOSDIS evolved to address user needs?

Over the last couple of years, the EOS scientific community has been critical of EOSDIS development, the attention to the user requirements, and the openness of the development of the DIS to scrutiny and advice. Over the last year there have been several changes which have resulted in much greater confidence by the scientific community. (1) EOSDIS funded and received reports on alternative architectures. (2) The EOSDIS Panel (advisory community of scientists) developed a working group on data production in order to define more carefully the data to be incorporated in the data and information system. This working group has been deemed highly successful and the information deemed critical to DIS design and implementation. (3) Following this success, a second working group has been formed to address the consumer "pull" of data. This is an open process and should address widespread concern that the user group has not been well-defined. (4) The Panel has agreed to coordinate peer review of the EOSDIS DAACs (Distributed Active Archive Centers). Peer review will be a significant element leading to improved efficiency and greater attention to user needs. (5) During the last year, for the first time, the connection between user needs and their budget implications was opened to scientific scrutiny. This step allows the scientific community to evaluate whether user needs are cost effective.

Each of these steps are significant, and address concerns of the EOS community which have been expressed over the last two years. I suspect that many scientists outside of the EOSDIS Panel and the Science Executive Committee of EOS are not yet fully aware of the many steps taken to address these issues, which are now also being expressed by GAO.

2. How well has NASA been able to preserve the scientific objectives of Mission to Planet Earth in the face of the substantial restructuring undergone by the program?

I believe that there have been some significant loses in terms of high resolution or innovative instrumentation. Budgets have also been cut across the board, including paring down instruments and freezing budgets of investigators, which were slated for some growth. Much of the effort to preserve the scientific objectives have resulted in increased risk (e.g. through designating some measurements as "Flights of Opportunity"), tolerance of some data gaps (e.g. ocean color) which will limit achieving some important scientific objectives, delaying some observations (e.g. measurement of the mass balance of ice sheets) which may well prove to be serious delays in understanding, and increased reliance on international partners. In some cases, this reliance will prove very worthwhile and mutually beneficial but in other cases (because international partners may end up with different priorities) greater risk is introduced. The last restructuring proved to be the most serious because of the very large number of observations which moved to higher levels of risk and which were lost or nearly lost. Additional budget cuts between now and the year 2000 will result in much greater loss of observations and a much larger impact on achieving EOS science objectives.

The strategies for budget cuts were widely debated among the EOS community during the major restructuring of the mission. Much of the greater risk, loss of observations and decrease in scientific effort could have been avoided, in each case, if the mission were allowed to slip. However, this was deemed to be the least justifiable mechanism to reduce the budget. All scientific investigators were willing to take budget cuts rather than delay the start of EOS observations. This indicates a strong sense of urgency in beginning the efforts to monitor global environmental change.

3. Mission to Planet Earth is intended to deliver a significant scientific return over the program's lifetime. Will Mission to Planet Earth provide any benefits to the economy as well? If so, what are they?

It is interesting that both the European Community and Japan have begun to develop strong environmental satellite programs and strong programs to develop predictive models of the climate system. In part, this may reflect a sense that these communities do not want to rely solely on the United States for such information. I believe, however, that a major part of this emphasis is the realization that prediction and advance warning related to monitoring the Earth system has tremendous economic value. The list of potential benefits, I suspect, is quite large. A few examples illustrate this point. Over the last several years, we have greatly enhanced the advanced warning for El Nino, in part through the monitoring system now in place in the central Pacific and in part through improved predictive models. Early El Ninos had substantial impacts on South American agriculture, with more global ramifications. It can now be demonstrated that the early warning has resulted in significantly less crop loss even during very severe El Ninos. The ability to predict seasonal, interannual or decadal weather or climate change either with the help of models or by identifying precursors to events evident from observations is likely to have widespread utility and benefit. Such predictions will be of particular importance for agriculture and for economic production associated with or limited by the availability of water and water resources. Similar benefits will be gained by increased prediction and assessments of major natural hazards, such as hurricanes or other severe weather. Ocean color observations, if utilized to enhance predictions associated with ocean productivity and fisheries will also be of value.

Given the nature of the U.S. role in the global economy, the global nature of many of these predictions and observations should also provide benefits in the assessment of global markets and stresses. Frankly, I believe that we are only beginning to assess the degree to which reliable predictive information on future environments will be utilized for economic benefit, both from the viewpoint of identifying new opportunities and from limiting economic losses.

"NASA: The Outside Opinion", a hearing of the
Subcommittee on Space and Aeronautics
March 16, 1995.

Questions for the Record to
Dr. Dan F. Lester, University of Texas

Answers submitted April 7, 1995

Question 1:

What would be the impact of delaying the start of the Stratospheric Observatory for Infrared Astronomy (SOFIA) beyond FY96, including the impact on the international collaboration?

Answer to Question 1:

For several years now, the SOFIA project has been a collaboration with Germany, in which 20% of the development and operations cost would be borne by that country in exchange for an equivalent fraction of the research time. German astronomers now participate routinely in studies with the current Kuiper Airborne Observatory, which SOFIA would replace, in many cases in collaboration with U.S. researchers.

From the perspective of new instrument development and scientific results, this partnership has been both close and productive. Such research partnerships will certainly continue, and sharing of astronomical data is a hallmark of our discipline that contributes to the common goal of basic research. The German interest in SOFIA is therefore an investment in making the project happen, and not a route to getting proprietary data.

Airborne astronomy has provided a strong scientific bond between our two countries — one of shared research, instrument development, and graduate education — and it is this bond that will be developed further by SOFIA.

NASA officials have informed the U.S. science community that, on the basis of discussions with their DARA counterparts, the German involvement in SOFIA is perishable. We understand that the Germans have expressed serious uncertainty about further postponing their investment to FY97.

If Germany is unable to participate in SOFIA, and its entire cost is borne by the U.S., then our obligation would be 20% higher than currently anticipated.

It must be emphasized that the scientific rationale for doing SOFIA is most certainly not perishable. As results from new ground- and space-based telescopes come in, as instrumentation technology rapidly improves, and as the Kuiper Observatory continues to age, the scientific need for SOFIA becomes increasingly acute.

SOFIA will be built with a used Boeing 747. Those available on the market are completely satisfactory, in terms of capability and condition. Such used aircraft will continue to be available, and the cost-saving relative to a new aircraft is enormous. However, current prices for these used aircraft are at an all-time low, and market projections indicate that they will soon rise. This rise would add to the cost burden produced if the German commitment were allowed to lapse.

By not starting SOFIA in FY96, we would be forced to accept the prospect that our cost to do it will sharply rise. On the basis of their long range strategic planning and budget projections, NASA officials have advised the astronomical community that such a cost increase would sacrifice the entire program.

Question 2:

If the SOFIA program is delayed, should the Kuiper Airborne Observatory program be reinstated until SOFIA is started?

Answer to Question 2:

The Kuiper Airborne Observatory, which SOFIA would replace, remains a scientifically and technologically productive facility. As the only airborne telescope in existence, it is unique in providing the astronomical community regular and continual access to the majority of the infrared spectrum of astronomical objects. For transient events, such as the 1987 supernova in the nearby Large Magellanic Cloud, this kind of access has proved essential.

The NASA plan, which is endorsed by the community, is the following. When SOFIA development begins, the Kuiper Observatory will be shut down in order to provide savings that can be applied to SOFIA. Since SOFIA development will take five years, it means that astronomers will sacrifice this profoundly important access to do space infrared astronomy for that period of time. The community sees this sacrifice as a painful but necessary investment in SOFIA.

Should SOFIA development be delayed, it is essential that the Kuiper program be reinstated.

RESPONSES TO QUESTIONS SUBMITTED FOR THE RECORD THE HONORABLE F. JAMES SENSENBRENNER, JR. AT THE HEARING MARCH 16, 1995 BY DR. C. W. FRANCIS EVERITT

1. *The Gravity Probe B budget lines contain $51.5 million funding for the program and then, in the next line, there's a $51.5 million "offsetting reduction." This is explained by a paragraph that says Gravity Probe B is under a National Academy of Sciences Review, and if the Review is favorable, then $51.5 million of program cuts will need to be made.*

   Should there be another National Academy of Sciences Study?

Response

Members of the gravitational physics community were surprised by the call for a new review, given the earlier strong endorsements of Gravity Probe B by three National Academy/NRC studies, including the Space Sciences Board's Strategy for Gravitational Physics in the 1980s (Shapiro Report 1981, 1982) and the ten-year survey Physics Through the 1990s (Brinkman Report 1986). In view of certain questions about the program voiced by persons from outside the gravitational physics community, however, Mr. Goldin's request for a new review may have been well judged. Accurate summaries of the scientific issues will be found in letters to Mr. Robert Walker by Professor Kip Thorne, of Caltech, and Professor Irwin Shapiro, of Harvard SAO, dated respectively March 2, 1995, and February 27, 1995.

2. *The Gravity Probe B program has been funded by NASA since 1984, and has undergone SEVENTEEN (17) studies and reviews to validate the scientific merit of the program.*

   Second, has Gravity Probe B experienced any cost overruns that would cause it to come before the NASA Program Management Council (described last year to this Committee) for termination?

Response

There have been no cost overruns. Gravity Probe B is within cost and ahead of schedule by twenty (20) months with respect to the NASA-mandated launch date of October 2000. Sunk costs as of the end of FY 1995 are $236M. The extensive prototyping already performed makes outyear costing unusually reliable. Baseline cost to (including MO&DA etc.) is $199M + launch vehicle ($60M). In addition, NASA is holding an $83M (=42%) construction contingency for a grand total of $342M. It is our expectation that some of the contingency can be returned to the taxpayer.

3. *During the February 13, 1995 hearing Mr. Goldin stated to the Members that Nobel laureates and influential members of the science community [are] questioning the validity of the GP-B program.*

   The testimony given by Dr. Everitt, responsible for GP-B at Stanford, quotes a Nobel Laureate on the validity of GP-B.

   Does it seem reasonable that a difference of opinion between Nobel Laureates should cause the cancellation of this or any NASA science program?

Response

The Nobel Prize is the highest award in science and the record of the Swedish Academy of Sciences in selecting Laureates is impressive. It must be recognized, however, that relatively few scientists even of Nobel stature have the broad vision that will enable them to make meaningful pronouncements outside their own specialty. C. N. Yang, who was quoted in the testimony, does have the right credentials as do others who have written strongly in support of Gravity Probe B, such as Subrahmanyan Chandrasekhar and Sheldon Glashow. Without knowing the names of the Laureates referred to in Mr. Goldin's testimony it is impossible to comment fairly. However, only one sure way exists for resolving differences of scientific opinion, and that is to perform credible experiments. The reason why each of the three earlier NRC reviews (and other reviews) supported Gravity Probe B is that it promises to resolve the issue with a well calibrated set of actual measurements.

4. *While flying more science missions can be possible under the "faster, cheaper, better" approach, how do you measure success in terms of scientific return? Published papers? Ph.D. dissertations? What measures scientific achievement for the investment?*

Response

Evaluating scientific return takes a summation of diverse factors (a) intrinsic technical merit, (b) balance, (c) educational impact, (d) efficient use of resources, (e) spinoffs. In each case the judgment requires a context. It may have to be qualitative, sometimes even intuitive, but that should not dissuade us from attempting it. So are many of life's more important decisions.

(a) *intrinsic scientific merit*: Peer review, with all its shortcomings, still seems the best method of evaluation, though scientists should recognize their responsibility to the wider public, including Congress.

(b) *balance*: More problematical, and more politically charged, is balance in the distribution of resources among different fields or institutions. Conventional peer review does not work well here. The only answer is to identify wise advisers of broad judgment. More generally one may think in the case under consideration that some modest percentage (5% say) of NASA's science budget should be dedicated to fundamental science, principally physics. Currently Gravity Probe B is NASA's only major fundamental physics program. At $50M/year it constitutes 1.5% of the science budget.

(c) *educational impact*: Broad views are needed in education. It is wrong to make the only purpose of a physics program to produce physicists or the only purpose of an astronomy program to produce astronomers. Cross-disciplinary experience, and institutional interaction between universities and NASA, would seem to have wider benefit in training creative individuals, as can be seen from the varied careers of the 54 Ph.D.s and still larger number of undergraduates trained on Gravity Probe B. It is worth emphasizing that the full benefit of an educational process seldom becomes manifest until the student is ten or fifteen years into his or her career. A succinct historical study of ours and other NASA programs would be of considerable value in measuring this impact.

(d) *efficient use of resources:* The recent NASA emphasis on "faster, cheaper, better" is an important corrective. Again there is a question of balance. Programs like Hubble Space Telescope serve a wide community and bring large light gathering power to astronomers that is beyond the reach of smaller telescopes. Programs like Gravity Probe B push the state-of-the-art in both science and engineering. "Faster, cheaper, better" has certainly stimulated creative thought. More generally the new NASA emphases on P. I. responsibility and product development teams are further constructive developments.

(e) *spinoffs*: In addition to specific short-term and long-term spinoffs, attention should be paid to the effectiveness of a program in fostering a spirit of inventiveness in students and others. Mr. Goldin on his visit to Stanford in December 1992 offered interesting comments about the difficult but important *process* for making transfer to industry of university inventions.

5. *With each NASA spacecraft program, there are two additional cost elements that are considered important: Research and Analysis, and Mission Operations and Data Analysis. These are necessary to pay for research on future spacecraft programs that may lead to new discoveries, and to capture data and make it useful information for science.*

Is there an appropriate ratio that should be applied to a mission's hardware cost, including instrumentation, versus R&A and MO&DA funds?

How much research funding should go with each dollar of spacecraft investment?

Response

No simple answer exists as to an appropriate ratio for MO&DA versus development costs. For Gravity Probe B the MO&DA will and should be low—around 3% of the program total. One reason for this figure to be so small is that there have been extensive simulations of MO&DA processes performed as part of the R&A aspects of GP-B.

For planetary and astronomy programs one may expect substantially higher MO&DA costs, though recent progress in computation and control may be expected to reduce these costs substantially in comparison with historical values.

A distinction should be made between R&A costs which are primarily for theoretical analyses and R&D costs for technology development. As was recognized as long ago as 1979 in the Harth report, the runout costs of NASA programs would be substantially reduced if more were spent up front on technology development before committing to flight programs. To some extent this has been done with AXAF, SIRTF and Gravity Probe B. Whenever it has been done the payoff has been significant.

QUESTIONS SUBMITTED FOR THE RECORD

FROM DR. BOYNTON

Questions for the Record submitted by
Subcommittee Chairman, F. James Sensenbrenner, Jr.:

1 NASA is starting to emphasize in its planning smaller, faster, cheaper, even in its science missions.

a What are the advantages and disadvantages in the trends toward using smaller spacecraft for space science and solar system exploration?

Smaller spacecraft have the potential advantages for accomplishing a significant part (but not all) of solar system exploration. They are less complex, more easily launched and delivered, and they can efficiently use modem technology to best advantage. The advantages can be realized, however, only if there is a continuing and relatively frequent series of these small missions to replace the occasional big mission of the past. Otherwise, most of the pressing issues will be left unaddressed. With small missions we can take advantage of the economies of accepting lower levels of reliability for any particular mission, since a later mission in the series could accomplish the goals of any failed mission. For the scientific community, small missions have the critical advantage that research can still be carried out on a broad front even with large budgetary pressures. This breadth is important since discoveries in "different" research areas are often important elsewhere (a good example is the solar "neutrino" problem) If a handful of large missions were to absorb all development costs over an extended period, the critical aspect of breadth would be lost from space science.

An additional advantage of small, inexpensive missions is **shorter** development times, which make it possible to work on current science issues with technologies that are up to date. With large missions that have a long development time, they can get "locked" into obsolete or partially obsolete problems due to the advances in technology or discoveries by other missions, especially foreign missions.

A disadvantage is that there is a tendency to think that ALL missions can be accomplished by small, cheap spacecraft. There is some science which is most effectively accomplished by taking advantage of the synergy of multiple kinds of global observations being made simultaneously by a number of instruments. Thus there are sometimes advantages for using a single launch to send an array of instruments to a planetary target to take a series of global, synoptic, complementary measurements. Moreover, some very important and significant investigations cannot be carried out with the foreseeable technology implemented in small missions. Detailed, robotic investigation of the surface of Mars, with roving, manipulation, drilling and analytical capabilities is one obvious example of this. Other disadvantages of small spacecraft are associated with physical limits in which new science comes from added sensitivity due to required stopping power or needed aperture. For example, a miniaturized Hubble Space Telescope makes no sense -- you need a big mirror to do the job.

b. Can New Millennium Spacecraft deliver good science?

Briefings on the New Millennium Spacecraft (NMS) program make it clear that this program is designed around technology development, with science playing a secondary role. NMS clearly CAN deliver good science; the question is WILL it? Right now, it is too early to say. It is clear that doing good science is not the aim of NMS, but developing technology to enable us to do good science with the "science driven" missions in the future is their aim. With the new trend to keep doing more for less, we will need this program. It should not be thought of as a science program, however. It is an investment for the future.

c. Can New Millennium missions perform Astronomy, or are they only useful in planetary and earth science?

I understand that NMS does have plans for demonstration mission that are astronomy related. Small missions can do excellent astronomy -- the proof is in the Small Explorer SWAS and WIRE missions. Small Explorers and Discovery spacecraft show that excellent science in Space Physics and Planetary Exploration can also be done with small spacecraft.

2 What would the biggest scientific casualty be from using small spacecraft missions to perform NASA science?

We see no casualties from using small spacecraft as long as they are launched frequently and we are not required to use small spacecraft exclusively. As mentioned above, many advances in space science come from complex missions, such as those that require significant robotics on a planetary surface, or from increasing the sensitivity of measurements with increases in mirror size, antenna lengths, stopping power, etc. These objectives cannot be satisfied with small-sized missions. The biggest casualties would be (a) if the regular frequency of small missions get pared back to being only occasional, instead of being launched at the several-per-year rate advertised, and (b) if they become the sole approach to space science such that we can never address the critically important scientific questions

3. Is there any fundamental science that we will not be able to conduct in the current fiscal atmosphere?

It depends on what is meant by "the current fiscal atmosphere"? According to Gingrich, Gore, Goldin, and others, we need to cut back on waste, inefficiency, unproductive consumption and -- instead -- invest more heavily in science and technology for the future. If THAT is the "atmosphere," one would think that we would be in a better position than ever to do space science. On the other hand, it looks like "the current fiscal atmosphere" actually means that science must take a disproportionate cut in its budget because so much of the Federal budget is "off limits." In this environment there are many important areas that are not being addressed.

While the administration's proposed budget carries out vigorous research in the Mission to Planet Earth, and Life and Microgravity Sciences and Applications, the Office of Space Science (Astrophysics, Planetary, Space Physics) was severely squeezed even before the additional $5 billion reduction ordered by the Administration in January 1995. In the current 5-year plan, the Office of Space Science (OSS) budget declines at over twice the rate of the agency average, totaling 20% by the end of the decade--even before inflation is considered. It appears uncomfortably likely that key areas of research in the OSS as identified in its September 1994 Strategic Plan will not be addressed in this atmosphere.

For example, in the Space Physics Division of OSS, there are no new missions from now through the year 2000. The key missions in the OSS Strategic Plan in this research area are the Solar Terrestrial Probes, which focus on the most important star, our sun, and its linkages with the most important planet, Earth. Beginning the Solar Terrestrial probes is urgent since studies of the upcoming solar activity maximum near the year 2000 require new starts in the very near future. While we fully understand the current budget constraints, the SSWG hopes that the Congress and NASA will work together to solve this out-year problem.

In addition to items that were dropped from the 1994 Strategic Plan, there are other important areas that we cannot even think of pursuing at this time. Missions such as returning samples from planets like Mars, which would dramatically increase our understanding of the planet, are farther from reality now than they were 20 years ago.

4 The 5-year budget run-outs submitted with NASA's FY96 budget show that a proportionally large share of cuts will come from Science, Aeronautics and Technology than from Human Space Flight. Please comment on this

The Office of Space Science faces a projected budget decline of about 20% in real year dollars between now and the end of the century, and about 35% in buying power -- assuming no further reductions due to the $5 billion further cut to the agency budget announced in January. Even so, in the OSS, this enormous decline in buying power will be partly absorbed through missions nearing completion and by scrubbing the MO&DA budgets of the ones that are operating. This makes it possible for OSS to propose several new initiatives (SOFIA, SIRTF, Discovery Series continuation) even with the declining budget. The problem is that the OSS is very tightly constrained, and that the Space Physics research area has no new initiatives We hope that the Congress, working with NASA, will limit the OSS decline in the future to match the agency-wide average of about 9%, in order to ensure that the nation's preeminent space science program can continue.

5 Does it appear to you that NASA is no longer striving for a balanced program of human and robotic spaceflight?

The rapid decline in the Office of Space Science budget, compared to "fenced off" space station funding, indeed shows that a crucial element of balance is lost in the current situation. Manned spaceflight is hurting, but robotic missions are hurting even more. Even if NASA is successful in taking the latest $5 billion in cuts from infrastructure, as seems likely, it may be that for the new, small NASA, the balance may still include too much infrastructure.

6. Does the Science community feel slighted by this action?

The Space Science Community has worked very hard over the past few years to bring the program into better alignment with budgetary realities while preserving an exciting, challenging, world-class research program. The community has absorbed cancellations (e.g., CRAF), has deferred indefinitely excellent missions (e.g., the Orbiting Solar Laboratory, Astromag, etc.), and has greatly reduced the cost of its current high-priority missions (SOFIA, SIRTF, TIMED, Solar Probe) while maintaining most of the science goals. With innovative programs like Discovery, the community is embracing new ways of doing business that deliver more science per dollar. Having made this effort, the community is of course disappointed that the current FY96 budget shows bigger cuts in OSS than in any other portion of the agency and threats of no new initiatives--even for those for which we have worked so hard to make room within the declining budgets. Since the OSS community has broader and deeper roots in the University community than other portions of NASA, these huge cuts directly impact NASA programs on campus that have long been an excellent source of recruiting students into the high-tech careers that are needed for a strong economy in the future.

Questions for the Record from Hall:

1. NASA is proposing to restructure its infrastructure to reduce costs. In order to help the Committee better evaluate NASA's proposals,

a. What do you think needs to be done to ensure that the health and vitality of the science program is preserved in a restructured NASA?

The SSWG agrees with the general approach of the agency that the first priority should be to maintain the programs and find ways to structure the agency to achieve this goal. This approach has the promise of maximizing the agency's output for a given budget size. In particular, we urge retention of the proposed new starts in the OSS (e.g., SOFIA, SIRTF, Discovery series, New Millennium Spacecraft) even as the agency is being reorganized, in order to better define the structure, direction, and goals, of the reorganization. There is some suggestion that science within NASA centers may also take a disproportionate amount of the cuts in the restructuring. If science is going to be "privatized," the money to support this operation needs to be accounted for elsewhere within the budget.

b. What do you think of the proposal to consolidate all science activities at one or two NASA Centers?

There is no evident merit to consolidation, if the goal is to reduce costs while preserving science. Science can be done increasingly effectively in a dispersed mode, thanks to modern telecommunications capabilities. All that consolidation of science activities in a single center will do is disrupt activities needlessly.

c. How important is it for NASA scientists to continue to have the capability to build scientific spacecraft "in-house?"

"In house" spacecraft construction serves as a key mechanism by which NASA employees can gain critical engineering and management skills, while at the same time supporting a vigorous science program. In the 1970's, for example, the Goddard Space Flight Center deliberately scaled down its spacecraft construction roles, with the result that after some years had passed, NASA "managers" with little or no hardware experience were called upon to manage construction projects out of house. This was not a satisfactory situation, since they did not have the knowledge and skills to manage the programs effectively. In the late 1980's, the Small Explorer (SMEX) program was set up "in house" at Goddard specifically to help rectify that problem. Now that the program is several years old, the positive results can be seen. SMEX-trained managers are being transferred elsewhere within GSFC, and bringing their skills and efficient approach with them. This success story shows conclusively that such in-house capabilities are critical. In the current "MIDEX" series of Explorer spacecraft, it is planned to procure some spacecraft from outside the agency, but to build at least some of the spacecraft in house at GSFC. We support this approach.

2. What is the impact on the field of space physics of the delay in starting the proposed series of small Solar-Terrestrial Probes?

The small Solar Terrestrial Probes line (a $40 million new start ramping up to a $70 million/year program) was an important part of the OSS Strategic Plan published in September 1994. The Solar Terrestrial Probes are missing from the FY96 budget and also from the run-out budget through the year 2000, which delays for these scientific goals in solar-terrestrial physics identified in the OSS Strategic Plan.

This situation leaves a critical hole in the OSS plan, since the Solar Terrestrial Probes focus on the most important star, our sun, and its linkages with the most important planet, Earth. Like the Discovery series, the Solar Terrestrial Probes employ small spacecraft and highly focused studies of solar variability and its influences. TIMED--the first of the Probes--will investigate the connection between highly variable short-wavelength solar radiation and the response these variations cause in the outermost layers of the Earth's atmosphere. Beginning the Solar Terrestrial probes soon is critical to allow study of the upcoming solar activity maximum near the year 2000. While we fully understand the current budget constraints, we hope that the Congress and NASA will work together with the science community to solve this out-year problem.

3 The proposed New Millennium spacecraft program is intended to fund future technologies that could be used in scientific spacecraft in the decades after the turn of the century.

a Given NASA's budgetary outlook, how would the SSWG prioritize the importance of starting the New Millennium program in FY96 relative to funding the other proposed science programs, i.e., the Discovery follow-on, the Mars Surveyor follow-on, SOFIA and SIRTF?

The SSWG recognizes the potential importance of the New Millennium Program for future technologies. The other proposed science programs are necessary in order to reap any benefit from the efficiencies associated with smaller, faster, and cheaper missions, but we need to develop new technologies if we are to be able to continue to cut costs. New Millennium probably need not be done this year, but it is our "seed corn" for the future and we need to get started with it as soon as possible.

b How would you compare the New Millennium spacecraft program to NASA's Lewis and Clark program?

The Lewis and Clark program is developing two Earth Observation spacecraft that cost $50-60 million each, and each weigh about 700 pounds. The product is well-defined, and supplements the agency's larger EOS initiative. It looks like the New Millennium Spacecraft program aims to take the Lewis and Clark idea and carry it further. They expect to achieve a higher degree of miniaturization with 100-200 lb spacecraft costing much less than Lewis and Clark.

c Would the objective of new technology development and insertion into science missions be best met by a dedicated technology demonstration program such as New Millennium, or by mission selection criteria for proposed scientific spacecraft series, e.g. the Solar Terrestrial probes, that would give preference to proposals that incorporate innovative technologies into the missions?

Developing technologies is not consistent with the smaller, cheaper faster approach to missions. Selection of a science mission based on giving a high weight for technology in the competitive selection process would be difficult. The development of the technology will necessarily be a high-risk venture with possible long delays. It is better to develop the technology without the risk of losing a big science mission and have the science missions evaluated on the basis of science, cost, and risk.

Responses to questions submitted for the record from The American Legion as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from the Congressional Budget Office as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from the NASA Aerospace Safety Advisory Panel, Mr. Norm Parmet, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Mr. Richard Kohrs, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Max Faget, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Professor Hans Mark, University of Texas, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Jerry Pournelle, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Scott Pace, of the National Space Society, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Mr. Bob Spitzer, The Boeing Company as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from the Office of Technology Assessment, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from the General Accounting Office, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Edward Teller, of the Lawerence Livermore Laboratory, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Eric Barron of Pennsylvania State University, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Dan Lester, University of Arizona, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. Francis Everitt, Stanford University, as requested by the Subcommittee on Space and Aeronautics . . . .

Responses to the questions submitted for the record from Dr. William V. Boynton, University of Arizona, as requested by the Subcommittee on Space and Aeronautics . . . .

Written Congressional Testimony
by Eric J. Barron
Director, Earth System Science Center
Pennsylvania State University

Subcommittee on Space and Aeronautics
U.S. House of Representatives
Committee on Science
March 16, 1995

The familiar global and regional environments on which we have come to depend are in danger of changing because of the effects of human activities, most notably due to the increases in greenhouse gases. Scientists no longer argue about whether human activities are modifying the Earth's climate. For example, we are certain that increases in carbon dioxide will promote changes in the Earth's energy budget with significant regional consequences. The primary scientific questions and uncertainties are associated with the rate of change and the magnitude of these changes. In addition to changes in greenhouse gases, the evidence clearly indicates that humans have transformed the landscape of the Earth and modified the chemistry of the atmosphere. Again, the key questions center on the nature of the impacts of these changes on climate, natural ecosystems, agriculture and water resources.

Three factors suggest a scientific strategy for the investigation of these issues. First, there are a large number of scientific uncertainties in addressing issues of global change. Second, I believe that it is far too costly to attempt to stabilize the emissions of carbon dioxide and other gases or, obviously, to alter the landscape. Third, all the changes to global and regional environment are not the product of human activities. These environments are also subject to modification because of natural variations in the climate system and natural biotic changes. Even without the activities of humans we can expect, because of natural variations, significant changes in climate, natural ecosystems, agriculture and water due to seasonal, interannual and decadal natural variations. These three factors suggest a specific scientific strategy to address the potential changes in global and regional environments. The key elements of this strategy are to monitor the changes to the Earth system and to develop better predictive capabilities to understand their impact, to be able to assess our vulnerability, and to make sure that the price of global change is not too costly in terms of its impact on our economic vitality or national security. This strategy is equally important to assess the impact of natural variations in climate as it is to assess the role of humans in altering the environment.

A focus on monitoring the changes to the Earth system and an effort to enhance our capabilities to predict the future are the strengths of the Earth Observing System (EOS), part of NASA's Mission to Planet Earth. Without EOS we lose this critical monitoring capability and we will lose our predictive edge.

EOS addresses the critical scientific questions which limit our ability to understand both natural variations and global and regional environmental change due to human activities. These critical questions include:

Can we predict, seasons or decades in advance, the climate in relation to both human and natural factors?

What will be the consequences of increasing greenhouse gases for both global and regional environments?

How will terrestrial and marine ecosystems, agriculture and water resources respond to changing climate, land cover change and other factors?

Can we understand the causes and impacts of significant changes in stratospheric ozone as well as detect changes in ozone amounts?

The Earth Observing System is essential to address these scientific questions and to enhance our ability to monitor and predict changes to the Earth System. A full set of these scientific questions, and the contributions of the Earth Observing System to national goals and needs, is appended as part of this testimony. A few examples are worth highlighting.

One of the major scientific issues limiting our knowledge of changes in climate is whether solar variations or greenhouse gas increases due to human activities are responsible for the temperature increases recorded over the last century. Importantly, without EOS we do not have a monitoring capability to measure changes in the sun. Without this monitoring capability we will not be able to separate these two effects.

A second major issue is the degree to which the loading of the atmosphere with particulates (aerosols) from various forms of combustion are partially counteracting the role to the greenhouse gases in promoting warming. Unfortunately, at present we can't describe the actual distribution of aerosols, their characteristics or the changes in aerosols with time. EOS provides the key opportunity to measure aerosol loading in the atmosphere. Both solar variations and aerosols are continually mentioned as factors which limit our ability to assess the magnitude and rate of global warming. We cannot afford to reach the next century without putting in place the capability to measure these important factors.

Many other scientific issues remain. Clouds and cloud-climate feedbacks have been repeatedly stated as the number one uncertainty in predicting future climate change. Unfortunately, we lack long term consistent measures of clouds and their radiative impact. Equally important, just observing the clouds doesn't provide the necessary information to predict the cloud cover when climate changes. We need to have simultaneous measurements of the meteorological factors which govern cloud formation in order to develop better predictive models. EOS provides the most comprehensive measurement capability to date, with synchronous measurement of multiple variables needed to make headway on this persistent problem.

Remarkably, we also do not have sufficient knowledge to determine whether the polar ice sheets are growing or retreating. This question is critical to determine sea level change on long time scales and its impacts on coastal cities. We also lack knowledge of where the carbon dioxide from burning fossil fuels goes after it enters the atmosphere. We need accurate descriptions of both terrestrial and oceanic biologic productivity to answer this important question. The sources and sinks of carbon dioxide determine the time period over which greenhouse gases will influence the climate. In both the case of ice sheet measurement and ocean productivity, the observations have already been placed at risk because of previous budget cuts to EOS.

EOS is also unique in many ways. It is unique in the involvement of quality scientists. It is unique in the emphasis on the data and information system to make sure that EOS is much more than hardware in its value to this nation. We can expect EOS observations to be of great importance well beyond the needs and uses of the scientists involved in this mission. It is also unique in the amount of science that is currently being undertaken prior to launch of the first satellites.

Just one sample of current research is submitted here as an example. Increased predictive capability is a key objective of Mission to Planet Earth. One of the most difficult variables to predict is precipitation. Yet rainfall is one of the most important variables in terms of its impact on agriculture, water resources and ecosystems. Figure 1 illustrates precipitation for March-April-May 1980 for the United States. Figure 2 illustrates the precipitation prediction for this same time period using a climate model typical of the types used to predict future climate change. We can see immediately that the prediction is not a faithful match of the observations. The problem is simpler than the solution. The global climate models require huge computer resources and so the modelers limit the spatial resolution to some 2000 points over the globe. Of course, much of the rainfall occurs at a much finer resolution than the models. Plus, the coarse resolution models can't incorporate the detailed physical descriptions of precipitation. One solution, being implemented by the Pennsylvania State University as part of the Earth Observing System, is to imbed a high resolution climate model with a domain only over the United States into the global model. The high resolution model then is forced by the global climate model. Figure 3 shows an example of the prediction of precipitation using this embedded model. The improvement in the prediction of precipitation is dramatic. Next (figure 4) will be a multiple embedded set of models of higher and higher spatial resolution in order to make detailed predictions of the water balance for important river systems, such as the Susquehanna River and the Chesapeake Bay system. EOS is leading the way in improving our ability to predict regional climate and environmental change. EOS will be essential in order to validate these model predictions for the coming decades and to improve the physical processes in these models in order to make better predictions of the future. EOS scientists are making enormous contributions in developing tools, analyzing existing data sets, improving models and in developing experiments to evaluate important physical processes, all in preparation for the launch of EOS satellites.

EOS is essential to monitor global and regional change and to increase the capability to predict future changes. EOS addresses the key scientific questions described above and provides the most rational strategy for addressing key uncertainties, for understanding the impact of human activities, to be able to assess our vulnerability, and to make sure that the price of global change is not too costly in terms of its impact on our economic vitality or national security.

Past budget cuts have already imperilled the effectiveness of the EOS program. Additional budget changes will result in a significant loss of science objectives. That is not to say that the scientific community is not willing to embrace new technologies and savings. However, these must be demonstrated and effective in gathering the critical observations without loss of schedule. Despite repeated budget cuts the scientists have maintained the launch dates of AM-1 and PM-1. We continue to make sacrifices, but we believe that there is an urgency to start these observations as soon as possible and to collect the best observations possible.

PENNSTATE
Earth System Science Center

OBSERVED PRECIPITATION (mm/yr)
March-April-May 1980

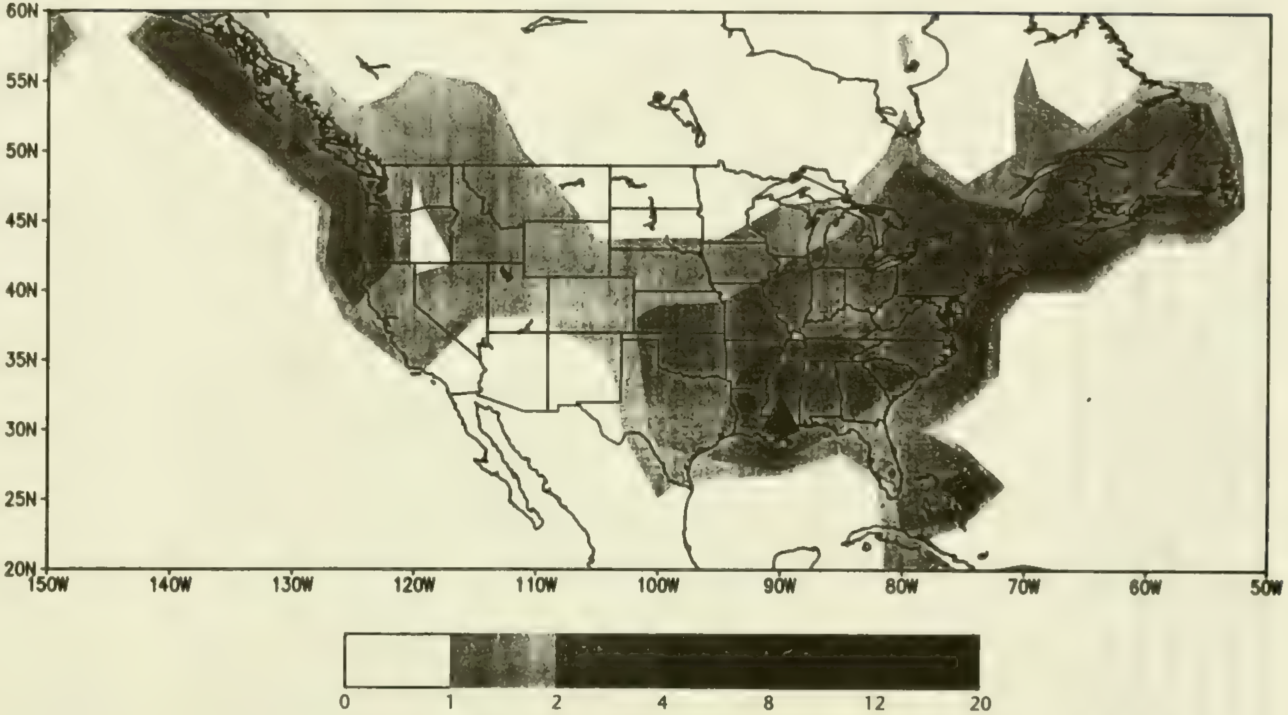

FIGURE 1

6A Ht

PENNSTATE
Earth System Science Center

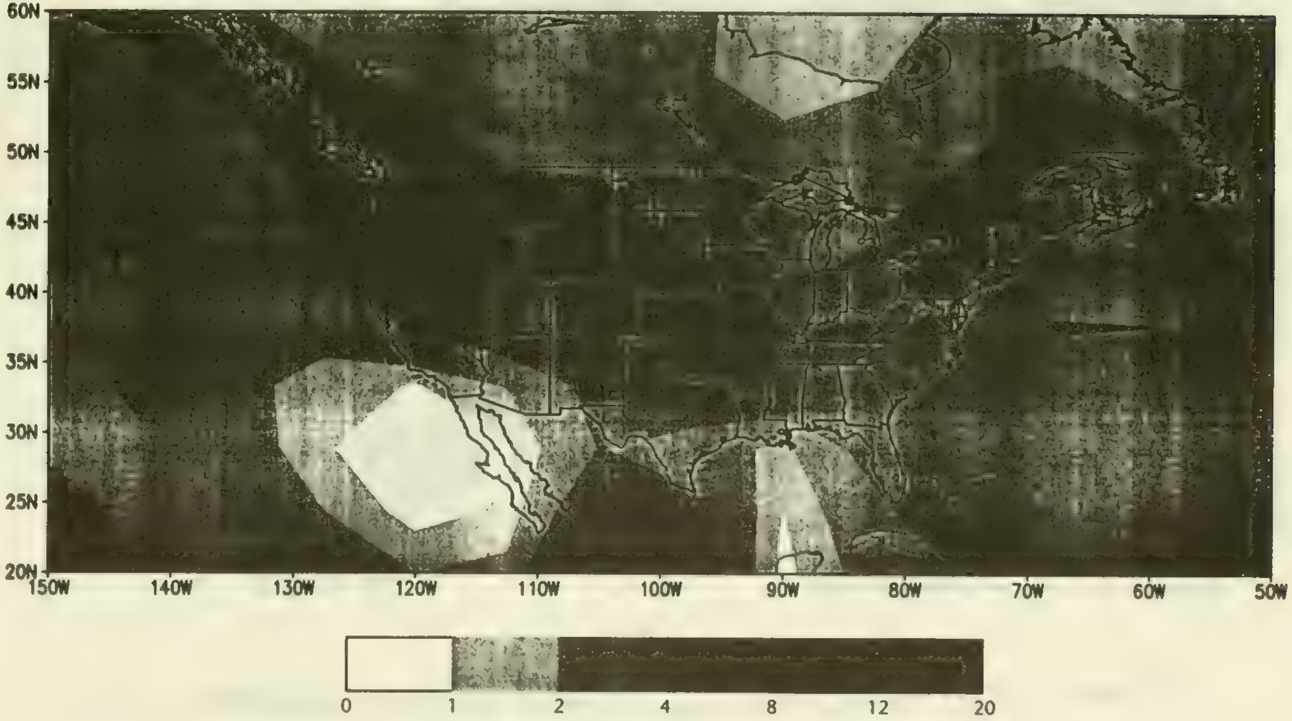
PREDICTED PRECIPITATION (mm/yr)
March-April-May 1980

FIGURE 2

7A Att

PENNSTATE

Earth System Science Center

NESTED MODEL PREDICTED PRECIPITATION (mm/yr)
March-April-May 1980

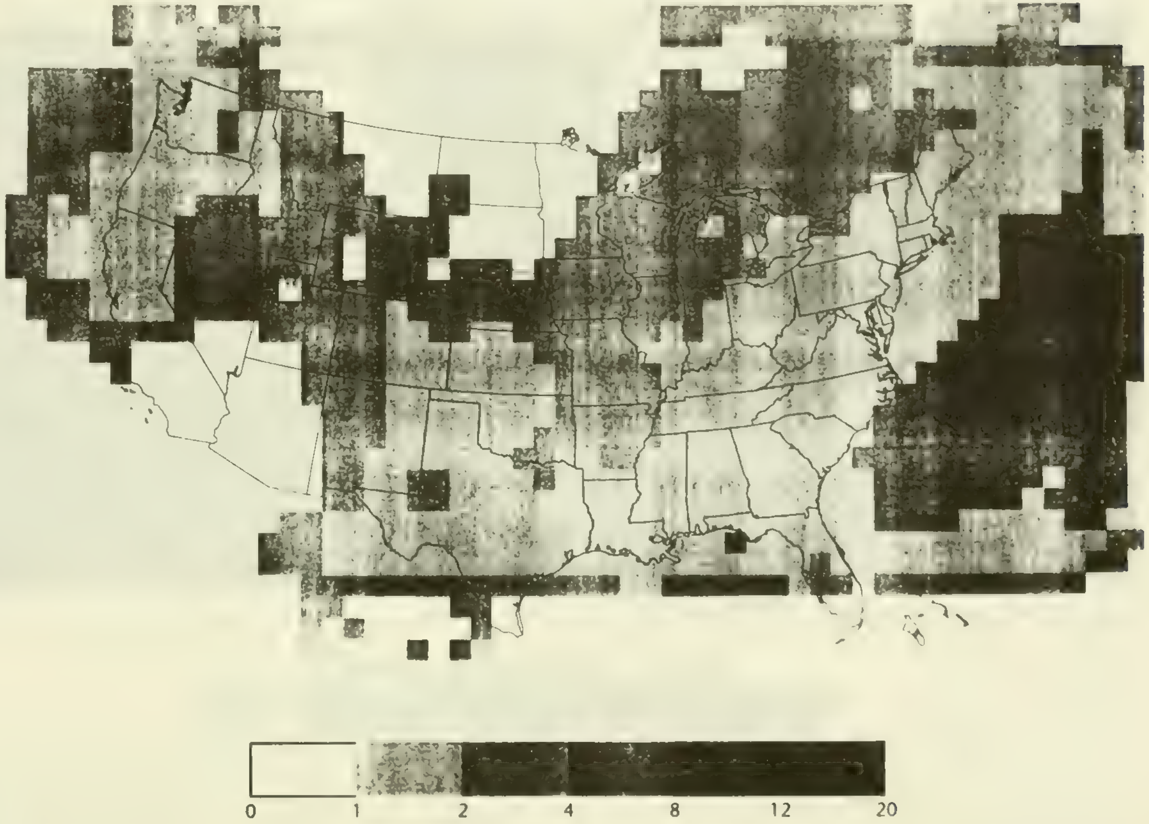

FIGURE 3

8 A 4+

Penn State/NCAR MM Domains

PENNSTATE
Earth System Science Center

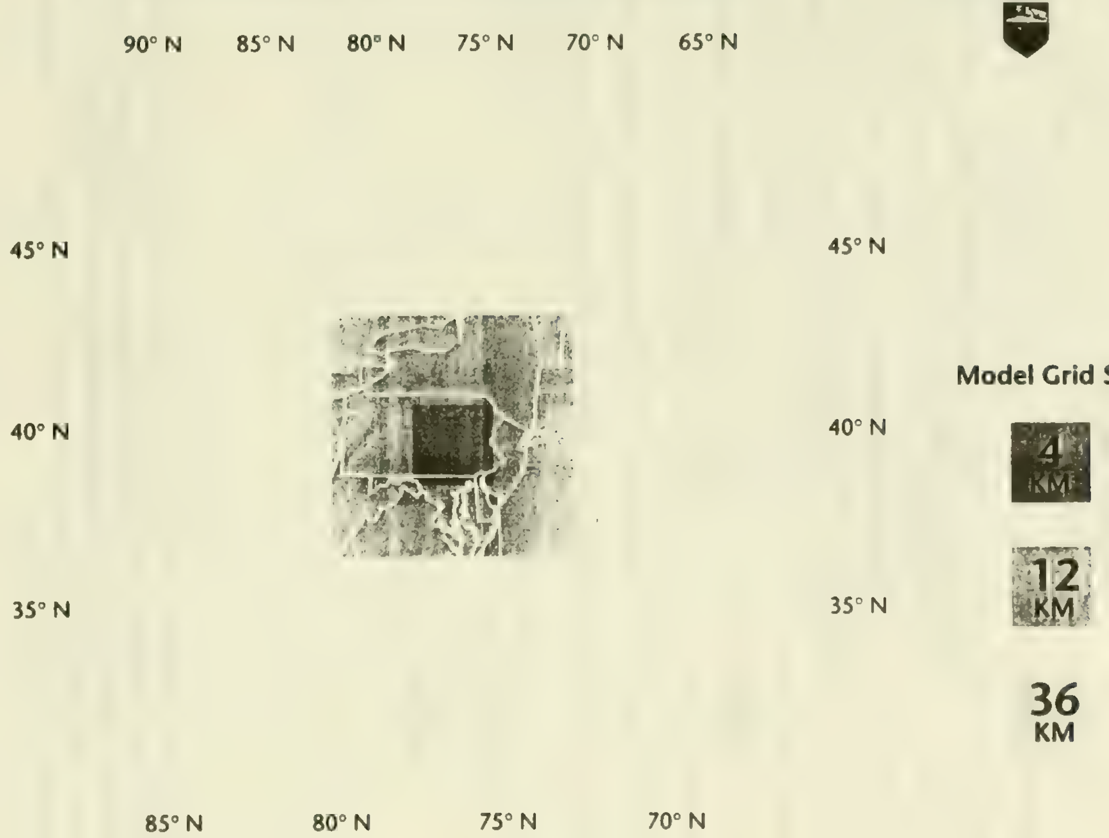

FIGURE 4

POLICY AND GLOBAL CHANGE RESEARCH
A Modest Proposal

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POLICY AND GLOBAL CHANGE RESEARCH
A Modest Proposal

Abstract

The history of the U.S. Global Change Research Program calls into question its sustainability. The Program was established on the presumption that a prerequisite for rational, comprehensive, and cost-effective policy responses is the reduction of scientific uncertainty through comprehensive predictive models. This presumption remains a significant barrier to the renewal of public support for the Program through near-term progress consistent with its mandate "to produce information readily usable by policymakers". This article critiques the use of comprehensive predictive models for policy purposes; proposes one modest alternative to comprehensive predictive models as a means of integrating scientific and non-scientific considerations into recommendations readily usable by policymakers; and places the issue in the broader context of a paradigm shift in U.S. science and technology policy. The purpose is to expedite progress, consistent with the policy mandate, that would help sustain public support for the Program.

POLICY AND GLOBAL CHANGE RESEARCH

A Modest Proposal

The U.S. Global Change Research Program (USGCRP) was established in 1989 as a presidential initiative to observe, understand, and predict global environmental changes induced by human activities on an unprecedented scale. In 1990, through Public Law 101-606 (Sec. 104), this multi-agency Program of scientific research received a policy mandate "to produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global climate change." Early in 1991, the Bush Administration affirmed a link between science and policy when it justified the Program as a means

> ...to reduce the significant uncertainty associated with predicting the behavior of the coupled ocean-atmosphere-land Earth system which determines climate phenomena and to form the basis for rational, comprehensive and cost effective responses to climate change. [OMB, 1991, 101-102]

Political advisers in the Bush Administration considered the reduction of scientific uncertainty a prerequisite to any major policy action. Scientific advisers in the interagency coordinating

Committee on Earth Sciences (CES) had already accepted (if not anticipated) this consideration.[1] CES focused on development of predictive models of components of the Earth system, and ultimately of the Earth system as a whole, to reduce scientific uncertainty.[2] The policy justification was no small factor in increasing the Program's focused research budget rapidly to $1.4 billion in FY 1994 and $1.8 billion in FY 1995.

However, the integration of science and policy in the USGCRP has become a matter of increasing concern, especially since the onset of the Clinton Administration.[3] It became apparent that for a decade or two at least the development of predictive models to reduce scientific uncertainty would be a substitute for "information readily usable by policymakers". Moreover, the interagency coordinating Committee on Earth and Environmental Sciences (CEES), like its predecessor [CES, 1989, 7], had disavowed policy analysis on scientific grounds:

> While recognizing that the principal objective of the Research Program on the

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[1] "Recognizing that effective and rational response strategies to environmental issues can be built *only* on sound scientific information," CES [1989, 8] wrote, "the overarching goal of the U.S. Global Change Research Program is: *To gain an adequate predictive understanding of the interactive physical, geological, chemical, biological and social processes that regulate the total Earth system and, hence establish the scientific basis for national and international policy formulation and decisions...*" (Latter emphasis is in the original.)

[2] The culminating scientific objective in the CES [1989, 17-18] implementation strategy was to "Develop Integrated Conceptual and Predictive Earth System Models": "Expanding knowledge of Earth system behavior is permitting the development of improved concepts and computer-based models, with the ultimate objective of developing predictions of global change and the impacts on human welfare on both global and regional scales." "Ultimately, the *long-term* thrust is the integration of those individual representations [of Earth system components, including human activities] into comprehensive, interactive models of the whole Earth system, with applications to regional and global scales." (Emphasis in the original.)

[3] Concerns were expressed by the President's Science Advisor in hearings of the Senate Committee on Energy and Natural Resources on March 30, 1993, and by various researchers in hearings of the Committee on Science, Space, and Technology [1993, 1994]. See also Miller *et al.* [1990], Brunner [1991], Monastersky [1993], and the Office of Technology Assessment [1993a, 1993b]. For an extensive evaluation of the implementation of the Program's policy mandate under CEES, see Pielke [1994].

> Economics of Global Change is to provide a solid foundation for policy decision making, a sharp distinction between economic research and policy analysis is enforced. Policy analysis, the short-term evaluation of specific policy proposals, is excluded from consideration under the Research Program on the Economics of Global Change. The credibility of the Program rests on vigorous enforcement of this distinction and adherence to scientific standards of review. [CEES, 1992, 3]

The expectation, evidently, was that policy analysis compromises scientific research. In November 1993, the Office of Technology Assessment concluded that "there is no formal mechanism in USGCRP for making the link between policy and science" [OTA, 1993a, 144].

In response to such concerns, CEES and its successor, the Committee on Environment and Natural Resources Research (CENR), did not seek a new mandate to rejustify the Program exclusively on scientific grounds. Rather, CENR [1994, 23] affirmed that "Most significantly, new research in FY 1995 will result in a better connection of research to policy making." And "Most importantly, the USGCRP plans to accelerate the development of methods for conducting integrated assessments, and assist in the conduct of some focused national and international assessments on differing time and spatial scales" [CENR, 1994, 81]. What this means is far from clear in 1994. For CENR, it apparently includes collaboration with social scientists to develop predictive models that maintain the distinction between scientific research and policy analysis.[4] For others, it apparently includes collaboration with decision makers in the formulation and evaluation of modest policies and programs, in series and in parallel, where the reduction of scientific uncertainty is *not* a prerequisite for action[5] -- in other words, something quite similar to the policy analysis earlier rejected on scientific grounds. It is still true that "assessment is a word that has really come to mean all things to all people" [Bierbaum in Committee on Science, Space, and Technology, 1993, 44].

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[4] For example, "Enhanced research on assessing policies and options...will involve leading social, economic, and policy scientists... whose collaboration with natural scientists and engineers is required to develop effectively integrated tools and models. Such collaboration is essential for addressing issues such as predicting the diffusion of new energy-conserving technologies, refining feedbacks within general circulation models that link human-generated emissions with climate, and identifying management strategies that can help preserve natural resources and biodiversity" [CENR, 1994:80].

This brief history calls into question the Program's sustainability, which depends on renewing public support through near-term progress consistent with the mandate "to produce information readily usable by policymakers". The Program's responses to public concerns are a step in the right direction but insufficient for at least three reasons. First, the Program's budget line for "Assessing Policies and Options" (including integrated assessents) is a thin periphery of less than 2% around a large scientific core.[6] Moreover, some funds at the policy perhiphery will be invested in the development of methods as opposed to policy applications. Second, the Program's acceptance of "Assessing Policies and Options" does not spontaneously eliminate the constraints that have shaped the scientific core of the Program from the outset [Earth Systems Sciences Committee, 1986]: There has been little enthusiasm for policy research that is perceived to compromise science; little understanding of policy research that goes beyond predictive models; and little opportunity to overcome the specialization of most global change scientists as scientists. One consequence of these constraints is a shortage of global change

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[5] For example, the hearings of the Committee on Science, Space, and Technology [1993] included testimony that "Resolution of all scientific uncertainties is not a prerequisite for policy action. Decision makers will apply their constituents' values to determine how much certainty they judge is enough to take a given policy action" [Bernabo, 49]; "An authentic policy-driven program for global change research would start from a decision maker's perspective [and] we must be concerned with a wide range of decision makers, not just those responsible for federal policy making" [Rayner, 66]; "Integrated assessment should adopt an iterative approach. It should begin with simple models, and only refine these when required by the underlying science and policy questions" [Dowlatabadi and Morgan, 87].

[6] According to CENR [1994, 110], "Assessing Policies and Options" comprised $16.9 million or 1.2% of the total FY 1994 budget of the USGCRP, $1,443.9 million. For FY 1995, the request for this line item comprised $34.7 million or 1.9% of the total request, $1,819.8 million.

policy scientists.[7] Third, the Program's responses have not alleviated public concerns. The Economist [1994, 85], for example, recently warned that "A global change science that prefers fiddling with ever more complex number-crunching models to the fuzzier assessments of human risks and impacts will eventually forget about saving the planet and lose its political support." Public concerns will not begin to be alleviated significantly until the Program demonstrates progress consistent with its policy mandate. Meanwhile, the Program will continue to draw down reserves of public faith, and the public will remain unprepared for global environmental changes.

This article addresses the problem of integrating science and policy in global change research, and considers the problem in broader context. The purpose is to expedite progress consistent with the policy mandate. The first section of the article provides a critique of comprehensive predictive models to reduce scientific uncertainty for policy purposes -- as distinguished from the scientific purposes for which such models make sense. The second section outlines one modest program designed to meet the criteria used in the critique: Scientific capabilities, procedural rationality, and political consensus in a representative democracy. This modest program along with some integrated assessments may be considered action alternatives to continued reliance on comprehensive predictive models. The third section considers the problem in the broader context of U.S. science and technology policy, in which the paradigm represented by comprehensive predictive models is giving way to another paradigm, perhaps one represented by modest action alternatives. The conclusion summarizes the implications for researchers and others with investments in the future of global change research.

I. Comprehensive Predictive Models

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[7] Based on participation in the OTA Workshop on Global Change Research and NASA's Earth Observing System, February 25-26, 1993 [OTA, 1993b], and the National Research Council's Workshop on Research Needs and Modes of Support for the Human Dimensions of Global Change, June 13-14, 1994) [Committee on the Human Dimensions of Global Change, 1994], the author estimates that no more than one in five participants had moved significantly beyond the scientific presumption on which CES established the Program -- even though participants in both workshops were selected because their interests went beyond science to policy.

Global change may be the largest policy problem in terms of the number of significant variables and interactions involved, and the scope of their spatial and temporal dimensions. Indeed, it is difficult to identify what is obviously *not* relevant to global change policy. But the presumption that we require comprehensive predictive models to reduce scientific uncertainty as a prerequisite for rational, comprehensive and cost-effective policy responses is nevertheless misplaced: The presumption seriously overestimates the predictive capabilities of science, the importance of predictions in rational decision processes, and the potential for political consensus on comprehensive policy.[8] A critique is in order for those for those global change scientists who are unaware of other perspectives on the integration of science and policy, and especially for those who have a latent interest in policy research.

Science

Any critique is complicated by the fact that successive coordinating committees have not specified what would constitute "an *adequate* predictive understanding of the interactive...processes that regulate the total Earth system and, hence establish the scientific basis for national and international policy" [CES, 1989, 8] (emphasis added).[9] Nevertheless, reliance on predictive models makes little sense if human behavior is taken into account -- and human behavior is central to the quest for policies to mitigate the anthropogenic causes of global change or to adapt human behavior to global change.

Without spectacular improvements in the forecasting of human behavior, a predictive model of the integrated Earth system or a subsystem would produce little more than educated guesses.[10] The record of forecasting for policy purposes shows that forecast accuracy is a function of the time horizon; there is no empirical basis for confidence in the accuracy of forecasts whose time horizons are measured in several years, much less decades. The record shows that forecast accuracy is a function of the validity of core assumptions, not methods; forecasts based on complex numerical models tend to be slightly less accurate than judgmental forecasts based on informal methods that leave some assumptions implicit. Finally, the record shows that complex numerical models are especially prone to assumption drag; their core assumptions lag behind changing reality and never catch up, in part because the models are relatively difficult to revise.

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[8] CENR has not declared this presumption inoperative and replaced it with another. The CENR has an opportunity to do so when it submits the 10-year plan for USGCRP. This plan was mandated by P.L. 101-606 (Sec. 104) and was due in November 1991.

[9] (The entire quotation was emphasized in the original.) For example, what variables would have to be predicted, on what geographical and time scales, how precisely, how accurately, how soon, and for whom? And how could we know *ex ante* that all significant interactions affecting those predictions had been included in the model? The same questions apply to comprehensive predictive models of lesser scope.

The limitations of large-scale models for policy purposes are illustrated in an experiment of the Modeling Resource Group of the National Research Council's Committee on Nuclear and Alternative Energy Systems published in 1978. Several different modelling groups projected the energy consumption and prices to result from six policy scenarios. Even though the groups used the same initial conditions and assumptions about economic growth, their results differed significantly -- for example, up to 19% for total energy consumption and 50% for electricity generation in projections for 1990 from the base case scenario. Similarly, shifts in policy scenarios produced significantly different results:

> ...the Brookhaven DESOM model and the Stanford University ETA model foresee little impact of a moratorium on nuclear development and limits on coal and shale oil exploration (compared to the base case), while the Nordhaus model (developed by William Nordhaus of Yale University) projects a 20% decline in energy consumption and domestic production under the moratorium conditions. [Ascher, 1981, 252-253]

It is an understatement that "some of the models must be wrong in quite significant ways on policy-relevant issues. It is also discouraging that even agreement across models need not be an indication of validity; they could all be wrong" [Ascher, 1981, 253]. For example, all multiyear predictions of U.S. energy consumption for 1975 turned out to be higher than actual consumption because none of them incorporated the possibility of an oil embargo in 1973-74. It is fair to conclude that complex forecasting models used for policy purposes do less to reduce scientific uncertainties than to express or to suppress them [Keepin, 1986].

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[10] Ascher [1978] is the classic appraisal of forecasting for policy makers; see also Ascher [1981, 1982]. For more recent but less comprehensive and systematic appraisals, see Malabre and Clark [1989] and Starobin [1993], for example.

Finally, scientists and policy makers who take the policy utility of predictive models for granted overlook this sobering assessment, based on logic and epistemology:

> Verification and validation of numerical models of natural systems is impossible. This is because natural systems are never closed and because models are always non-unique. Models can be confirmed by the demonstration of agreement between observation and prediction, but confirmation is inherently partial. Complete confirmation is logically precluded by the fallacy of affirming the consequent and by incomplete access to natural phenomena. Models can only be evaluated in relative terms, and their predictive value is always open to question. The primary value of models is heuristic. [Oreskes *et al.*, 1994, 641]

Consequently, what is omitted from a model can nevertheless impinge on the open system it represents and undermine the accuracy of the model's forecasts. For example, the oil embargo of 1973-74 upset the stable, predictable ratio of gross domestic product to energy consumption in the U.S. As the embargo suggests, political leaders can deflect the momentum of history under some circumstances [Trevor-Roper, 1980], but political leaders are themselves subject to change through elections and other means. Thus the outcomes of future elections world-wide could significantly affect global change impacts and policies, but the causes and consequences of elections cannot be incorporated successfully in comprehensive predictive models. For example, the re-election of President Bush in 1992 was considered highly probable in 1991, after Operation Desert Storm. Thus politics are often the missing link in forecasting [Ascher, 1982]. Moreover, chaos theory demonstrates that differences smaller than the level of measurement error can make all the difference in system behavior under quite general circumstances [Glieck, 1987].

Alice M. Rivlin, the former director of the Congressional Budget Office and current official of the Clinton Administration, has expressed her judgment on the past and future of economic forecasting, the policy area in which we have the most experience forecasting human behavior:

> The poor showing of the forecasters is not due to any lack of effort or ingenuity... The real problem is that the economic system is extremely complicated, that our own economy is battered by forces outside itself which are inherently unpredictable, such as the weather or foreign wars. I doubt we will ever improve the accuracy of forecasting very much, especially the forecasting of economic turning points. Instead, we will have to learn to live with the uncertainty. [Rivlin, 1984, 20]

There is more than a little hubris in the presumption that scientists can develop a comprehensive predictive model of the integrated Earth system or its subsystems that would reduce scientific uncertainty as a prerequisite for rational policy. Numerical models are useful in projecting the consequences of assumptions, but such projections are not reliable predictions. If reliable predictions were a prerequisite for action, the world would grind to a halt.

Rationality

From a policy perspective, the purpose of science in human affairs is not prediction but freedom through insight [Lasswell, 1951, 524-525; 1965, 76-77]. Scientific uncertainty (or the *in*ability to predict with precision, scope, and accuracy) is an indication that the future is not determined by immutable laws of man or nature. Scientific insight brings unconscious and unperceived factors in the self and the environment into conscious awareness so that people are free to take them into account in making choices and decisions. Thus freedom through scientific insight helps people make more of their limited capacity for rational decisions, but at the same time exacerbates scientific uncertainty and undermines the accuracy of predictions.

A predictive model is neither sufficient nor necessary for improvements in the rationality of policy decisions. A predictive model is not sufficient because projecting the consequences of action alternatives, by numerical model or other means, is only one task in a rational decision. The other tasks, for which traditionally-trained scientists have no special competence, include clarifying policy goals, evaluating policy alternatives, and reconciling the inevitable policy differences through politics. A rational decision integrates goals, alternatives, and politics with the best available scientific projections; a rational decision process reintegrates these considerations as circumstances change [Hogarth, 1981; March, 1982; Simon, 1983]. Scientific projections must be made as objectively as possible, but they must also adapt to changes in goals, alternatives, and politics in order to remain relevant [Kaplan, 1963; Lasswell, 1971]. The integration cannot be taken as given once and for all; mere mortals must allow for the possibility that their earlier preferences or expectations were mistaken.[11]

A predictive model is not necessary because it is procedurally rational to act on an alternative despite uncertain consequences, ambiguous goals, and political differences -- provided the alternative is modest enough to fail gracefully, to discover what works in the field, and to learn from the experience. Under these circumstances, projections need only be reliable enough to identify the most promising alternatives among those available. The most reliable projections will be modest in geographic scope and time horizons, thereby minimizing vulnerability to remote events that cannot be adequately anticipated or controlled. The most useful projections will be contingent on specific goals, alternatives, and political considerations too numerous to include in a model of large scope. The most cost-effective alternatives will tend to differ from one locality or region to the next. For these reasons, action on a modest policy tends to be more rational than action on a comprehensive policy that covers more elements of a problem, a larger geographic area, and a longer period of time. A comprehensive policy also restricts, delays, and increases the costs of learning from experience to the extent that it depends on the coordination of massive resources [Brunner, 1992; Collingridge, 1992].

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[11] Bierbaum affirmed these theoretical points before the Committee on Science, Space, and Technology [1994, 44]: "Iterative, integrated assessments should both guide rational decisionmaking and, in turn, help shape the evolving research agenda. End-to-end assessments to OTA does not mean go from the science end to the policy end, but iterative end to end. Policy concerns, in turn, feed back into defining key research needs that may change over time." .

Finally, waiting for predictive models makes little sense on those parts of the global change problem for which field-tested action alternatives are already available. For example, in the aftermath of the 1973-74 oil embargo, millions of American households, firms, and local and state governments learned how to conserve energy, to use it more efficiently, and to begin developing renewable energy resources [Brunner, 1980].[12] Building on that experience would mitigate the accumulation of atmospheric CO_2 in some degree. More importantly, it would nurture the decentralized knowledge and skills (of scientists and decision makers alike) that are necessary to adapt to the diverse local and regional impacts of global change. The Clinton Administration's Climate Action Plan and other initiatives of the federal government can support such decentralized decisions. The general strategy is to factor the overall problem into distinctive geographic or functional parts, and to proceed modestly whenever and wherever action makes sense.

Politics

A comprehensive policy proposal based on a comprehensive predictive model is not likely to win political consensus because the powers of government are separated among the three branches and shared with the fifty states, and because modern society is fragmented into myriad special interest groups. A comprehensive policy proposal would attempt to coordinate many actions on many fronts at the same time, but it would be far from objective or value free: What appeared to be rational (or otherwise justifiable) from the central perspective of White House planners would be quite the opposite from the diverse perspectives of the many interest groups to be affected by the proposed actions. Each group would have the opportunity to concentrate its political resources on the defeat of the particular proposals it considered most adverse. In contrast, the White House coalition would have to deploy its resources thinly to defend the many actions incorporated in a comprehensive policy proposal. Thus on some fronts, the White House coalition would find itself at a disadvantage despite control of more political resources than any single opponent. The prospect of losing on key proposals might prompt Presidential appeals to the public to suppress particular interests on behalf of the national interests at stake. But such appeals are not likely to succeed in the absence of extreme crisis or high levels of public trust and Presidential credibility.

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[12] This happened despite the emphasis in federal energy policy on stimulating the domestic production of energy through large-scale technologies -- some conventional and some exotic, such as breeder reactors, synthetic fuels, and shale oil -- that required centralized decisions. Decentralized decisions nevertheless contributed more to meeting the nation's energy needs in the decade after the embargo [Iott, 1992a].

A case in point is the National Energy Plan (NEP) developed by the White House energy planning staff in 1977. In promoting the Plan through national television and other media, President Carter characterized it as the alternative to national catastrophe, and as "a carefully balanced Plan, which depends for its effectiveness on all of its major parts."[13] But the comprehensive legislation to implement this carefully balanced Plan was submitted to the Congress, and there it was broken up according to the jurisdictions of various committees and subcommittees. Both members of Congress and special interest groups considered most of the proposals more or less independently of the others. It took a year and a half to enact five bills that only loosely resembled the initial legislation. Apparently, the attempt to justify the USGCRP as a basis for comprehensive policy overlooks the NEP precedent and subsequent declines in public trust and presidential credibility over the last decade and a half.

In any case, a comprehensive predictive model used for policy purposes would not be above politics or value free. The promise of such a model has already been used, unwittingly or not, to direct public concerns about global change from policy action (such as decentralized energy policies) to scientific research under the USGCRP. A comprehensive model is inherently biased toward centralized decisions because it could not be detailed enough to include more than the grossest regional differences: It would discount or ignore most of the relevant geophysical, social, and political differences among such distinctive localities and regional centers as Boston, Detroit, Seattle, Los Angeles, Houston, Kansas City, Atlanta, Miami, and a host of others. Finally, a comprehensive model would become a political asset for the very few who understood and controlled it; and it would not be unprecedented to use a comprehensive model to "absorb" uncertainties in ways that promote *a priori* policy positions.[14] For example, in 1977 the White House energy planning staff used the Project Independence Evaluation System (or PIES model) to inflate by a factor of four the savings in energy imports attributed to the National Energy Plan [Commoner, 1979, 15].[15]

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[13] From his covering letter, dated April 29, 1977, reproduced before the text of Energy Policy and Planning Staff [1977]. See also Carter [1977].

In summary, the emphasis on predictive models of the integrated Earth system and its subsystems for policy purposes is misplaced in several respects: It overstates scientific capabilities to predict human behavior accurately over long time horizons and on national or international scales; it inflates the significance of scientific predictions relative to other components of rational decision processes and to field-tested action alternatives already available; and it overestimates the possibility of consensus on comprehensive policies in an open political system with low levels of trust and credibility. The acceptance of comprehensive predictive models for policy purposes reflects a paradigm that has been accepted implicitly or explicitly for many decaades, but has become controversial in recent years. That paradigm is reviewed in the third section below.

II. A Modest Alternative

Modest alternatives to comprehensive predictive models merit consideration for policy purposes. Through action on multiple modest alternatives we can more quickly and reliably discover what we need to know to mitigate or adapt to global change. This section outlines one modest alternative -- a national program based on decentralized policy teams that would disaggregate problems of global change geographically, integrate and reintegrate policy-relevant knowledge for various decision makers through time, and compete for continuing support from the federal government on that basis. Of course other modest alternatives, including some integrated assessments, are also worth considering as bases for action and as opportunites for nurturing policy skills among global change scientists.[16]

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[14] "Knowledge is a form of power, and most institutions exhibit an understandable reluctance to dissipate this power in the absence of compensating advantages" according to Schlesinger [1968, 282], who directed the White House energy planning staff in 1977.

[15] Similarly, a project of the International Institute for Applied Systems Analysis (IIASA) claimed to have used interconnected computer models to draw energy policy conclusions that were globally comprehensive and inescapable. A subsequent appraisal demonstrated that the conclusions were little more than restatements of data inputs that had been acknowledge as highly uncertain; and that some of the computer models had not been built [Keepin, 1984; Keepin and Wynne, 1984].

Program Description

The primary goal of the modest program is to realize continuous improvements in the information (including recommendations) readily useful and available to public officials and private citizens whose decisions affect, or are affected by, global change. The relevant decision makers are not limited to federal officials alone because even the most centralized policy could only be implemented through the decisions of many others. If the primary goal cannot be realized satisfactorily and at acceptable cost, the secondary goal is to understand why not -- in order to clarify whether a successor program makes sense and, if so, how to proceed. The secondary goal allows for a partial success even if the primary goal turns out to be too ambitious.

Five basic operating norms are key to the program's success given the present limited understanding of global change for policy purposes:

1. Support a modest number of teams (at least 6 or 7) for a modest period (perhaps 2 to 3 years) to work concurrently on improvements in the policy information readily useful and available to decision makers in the localities or regions in which the teams live, or otherwise have special competence.

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[16] Similarly, in the hearings of the Committee on Science, Space, and Technology [1993, 87], Dowlatabadi and Morgan affirm that "There is no single right way to do an integrated assessment. Nationally, our chances of success will be greatest if several different groups, both inside and outside the government, engage in such activity in a healthy spirit of intellectual competition."

2. Allow each team broad discretion to define its own approach in order to encourage a diversity of approaches *to* the primary goal and *for* the secondary goal. Discretion would include geographic focus and boundaries, specializations included in the team, research strategies, and interfaces with decision makers.

3. Evaluate the teams' work comparatively in terms of the primary goal at a policy research conference about six months before the end of current support. The conference would be comprised of federal officials, leaders or principal investigators from every team, and selected associates or clients of the teams.

4. Select those teams that have made the most progress on the basis of the comparative evaluation to reapply for continued support in the next period. Those teams that have made the least progress (one or a few at least) are effectively terminated because their results fell short of the standards set by the leading teams.

5. Repeat the cycle of support (replacing terminated teams with new teams on the basis of competitive proposals) so long as the federal officials represented in the research conferences consider progress according to the primary goal sufficient to justify program costs.

The operating norms are designed to evolve improvements in the information readily useful to decisions maker by exploiting the differences among localities and teams. From the standpoint of procedural rationality, it is not necessary to presume that anyone knows enough to prescribe *the* mechanism for integrating scientific and technical information from global change research into policy recommendations. It is sufficient to organize a process that maintains a diversity of plausible approaches, selects the approaches that have succeeded on the basis of field experience, and cumulates the successes. It is advisable to simplify the national problem by factoring it into distinctive geographical components.

The resources required to initiate the program with an opportunity to succeed are modest and flexible. The initial budget requirements depend primarily on the number and the average budget requirements of the decentralized policy teams. (One possibility is to fund each team at the same level in order to level the playing field.) The initial budget could be as low as several million dollars per year, which is a trivial fraction of the total federal effort in global change research. The budget for the next cycle could be expanded (or contracted) depending on the progress made (or not made) in the previous cycle. But too much budget too soon runs the risk of turning the program into a cash cow for special interests that are not necessarily compatible with the program's primary goal. Experience suggests that resources may be diverted toward substitute goals, including more funding for scientists, more growth for agencies, or more jobs for other constituencies of the executive branch or Congress. The issue is less *how much* budget than *how* the budget available can be applied most effectively toward the goals used in the program's public justification.

People motivated to make the program work according to its justifying goals are the key resource. Such people are most likely to be found among decision makers, the end-users of the program's research, who are seldom in a position to participate intensively in research that extends well beyond their limited authorities or jurisdictions. However, a policy research conference every two or three years would give decision makers and members of their staffs -- from the Congress, the executive branch, the localities and regions, and the private sector -- direct access to presentations and evaluations of the teams' research without the burden of day-to-day involvement. Competition among the teams would generate different policy recommendations, and thereby open up alternatives from which decision makers might select. This could be enough for them to shape the direction of the program according to its justifying goals. Moreover, if the teams expected to be evaluated on the basis of information readily usable and used by decision makers, the teams would be motivated to consult with decision makers between research conferences.[17]

Organizational independence could be another key resource, if significant resistance to policy research persists within USGCRP. An independent modest program would be in a better position to focus on improvements in policy information and recommendations without the burden of meeting scientific standards which (as interpreted by CEES) preclude policy analysis. A USGCRP relieved of its policy mandate would be in a better position to focus on improvements in the scientific understanding of global change without the burden of justifying its results as readily useful to policy makers. For each program, a distinct and sharper focus would enable program officials to manage more efficiently and outsiders to exercise more responsible and effective oversight. This would give both programs a better chance to succeed according to their overlapping but distinctive purposes. Organizational independence would *not* prevent the programs from sharing results and personnel. On the contrary, to remain competitive, the teams in the policy-directed modest program would be motivated to recruit scientists of various specializations and to integrate the best scientific information available into action alternatives -- thereby building demand for global change research. The managers of the science-directed USGCRP would be motivated to consider new scientific questions that are relevant to decision makers attending the research conferences, in order to cultivate the long-run support of those who do not regard scientific research as an end in itself. The point of organizational independence would not be to insulate the programs, but to minimize central control over the interface between scientific and policy research by multiplying informal contacts among participants in the programs.

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[17] This would be consistent with P.L. 101-606 (Sec. 102), which includes a mandate "to consult with actual and potential users of the results of the program to ensure that such results are usable..."

Finally, the modesty of this program should not obscure the critical but neglected problem it addresses. That problem is the integration (and reintegration as circumstances change) of scientific and non-scientific knowledge into action alternatives from which decision makers can choose. Integration is critical because an integrated assessment based on scientific knowledge alone is inadequate for policy purposes: It would have to avoid explicit consideration of policy goals and action alternatives to meet scientific standards as interpreted by CEES; and even if it included them, it would have to be interpreted for various specific local or regional contexts to become a map for action in them. Integration is neglected because the increasing specialization of knowledge in the modern era leaves few scientists prepared to cope with a policy problem, even if they are motivated to try: The decade or more required for expertise in one specialization means ignorance of most other relevant specializations; and that ignorance is reinforced when careers depend upon peer review according to the standards of the specialization. Moreover, decision makers and their immediate staffs normally do not have sufficient time or expertise to do the integration, or do it well, for non-routine decisions on complex issues. If they do have sufficient time and expertise, they do not need the assistance of global change researchers.

Program Rationale

Why does this modest program merit consideration as one means of providing information readily usable by policy makers? Because theory and cases suggest that a modest program like this simplifies policy research in a manner more consistent with scientific capabilities, the requirements of rational decision, and the need for political consensus in an open system. Of course the definitive test of this or any other program depends upon the experience that would follow from implementation.

Science. Disaggregation geographically is the appropriate means of simplification for purposes of global change policy research [Glantz, 1988; Sylvester, 1990; Rayner, 1993]. It is clear that any global environmental change will not be uniform across smaller geographic areas: An increase of 2 degrees C. in average global or national temperature says little about the magnitude or direction of temperature change in any particular region. Moreover, even a change that is uniform across some regions may interact with regional differences to generate quite different impacts: An increase of 2 degrees C. may stimulate precipitation in one region and desertification in another. Finally, the best policies to mitigate or cope with the diverse impacts of global change will differ according to the more or less distinctive value priorities, institutional capabilities and natural resources of the locales or regions. In a future environmental crisis, as in the energy crises of the 1970s, what makes the most sense in one locale will not necessarily make sense for most other locales or for the nation as a whole.

Simplification comes through intensive focus on locales that are representative of larger areas. It is true that each locale is unique, if described comprehensively in terms of the many variables relevant to global change policies. Even if only fifty dichotomous variables were significant, there would be 2^{50} possible combinations of characteristics -- a number orders of magnitude larger than the number of villages, towns, and cities in the world. Hence, by the conjunction rule of probability, there is likely to be no actual instance of most of the possible combinations of 50 characteristics, and only one instance of the remainder. Some locales nevertheless will have enough similarities among themselves, and enough differences from others, to be distinguished as a region; and within each region some locales will be more typical than others. Action alternatives developed for one or a few of the prototypical locales could be readily diffused and adapted to other locales in the region; and to that extent, further intensive research on additional locales in the region would become increasingly redundant.[18]

Simplification by intensive focus on regional prototypes is more appropriate than the alternatives because it is better adapted to the geophysical, social, and political structure of policy problems. Simplification by aggregation of variables to the national or international level is an alternative that would suppress local and regional differences. It is not clear that comprehensive policy solutions exist; but it is clear that comprehensive policy proposals should be suspect until differences among locales or regions have been taken into account. Simplification by deletion of relevant variables is an alternative that would undermine the realism of policy advice. The most likely candidates for deletion are the social and political variables grouped under the human dimensions, which are difficult to quantify and interrelate but nevertheless central to global change policy research. An integrated assessment is an unfulfilled promise to the extent that the human dimensions are discounted or ignored. Finally, "fixing" variables (by taking them as exogenous or given) is a alternative simplification that would suppress degrees of freedom in coping with global change problems. The most likely candidates are policy goals and action alternatives, which CEES excluded on scientific grounds. But alternatives and goals should be subject to change as new scientific insight or other events undermine their realism or worth.

Rationality. Decentralized policy teams would make the most of our limited capacity for rational decisions despite scientific uncertainties, ambiguous goals, and political differences.

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[18] On the scientific rationale for this neglected strategy of simplification, see Sokal [1974]. For an example and additional references, see Brunner [1986].

Each team can simplify by focusing on only those particular scientific projections, goal priorities, practical alternatives, and political and social considerations that are important in its own locale over the next few to several years. Considerations that are more remote in time and space cannot be reliably anticipated or controlled, but they can be reasonably discounted if the practical alternatives are modest by design -- that is to say, focused on a single objective, designed for evaluation within a few years, and implemented separately even if they are part of a larger program. Action on such modest alternatives is more likely to yield clear evaluation results before their assumptions are undermined, to be terminated without compromising the larger program if they fail, and to be replaced as their termination frees up resources. Progress does not depend on the reduction of scientific uncertainty as a prerequisite to action on a national or international scale; progress depends local actions, in parallel and in series, designed in part to clarify expectations, preferences, and political realities through experience.

From this standpoint it was rational in late 1975 for the City Council in Davis, CA, to approve an energy conservation building code that indirectly mandated the use of passive solar heating and cooling process in new residential construction. This modest action was adapted to local circumstances, not national or global circumstances. Its primary objective was to reduce residential energy consumption at little or no cost, not to solve all energy, environmental, or consumer problems on a comprehensive basis. Its energy savings and costs could be readily evaluated when the first new residential units were built under the code and compared with units built under the previous code. And the new code could be terminated, if necessary, before large numbers of units were built [Subcommittee on Energy and Power, 1979; Brunner, 1980]. Similarly, it was rational in 1976 for the Seattle City Council to pass up long-term participation in the construction of nuclear power plants proposed by the Washington Public Power Supply System (WPPSS), which would have been a major commitment of at least a quarter of a billion dollars according to estimates at the time. Instead, to meet its electricity needs to 1990, Seattle adopted a more flexible conservation and efficiency policy to be implemented initially by thirty-two specific programs [Subcommittee on Energy and Power, 1979; Brunner, 1980]. Similarly, it was rational for the Wisconsin Public Utility Commission to mandate least-cost alternatives to meet new electricity demand. For the state's largest utility, this forced a shift from additional nuclear generating capacity to conservation and efficiency programs and to small, modular, coalfired generating plants that could be built in about four years [Munts, 1987; Porter, 1987].

Such modest actions can be replicated or adapted, and their effects thereby multiplied, through diffusion of the prototype to other communities. Three conditions expedite diffusion: (1) Other communities are sufficiently dissatisfied (or otherwise motivated) to be receptive to alternatives; (2) the prototype was in fact an alternative worth emulating; and (3) interactions among the communities are sufficiently frequent and continuous to establish de facto standards of performance. Under these conditions, the communities that lag behind the standards set by the leading communities are pressed to emulate the leaders or to explain why not -- an outcome approximated in the case of mandates for least-cost electricity alternatives, which have diffused to most of the fifty states and earned technical assistance and regulatory relief from the federal government [Iott, 1992b]. The modest program proposed here incorporates decentralization to stimulate the demonstration of successful prototypes, competition to motivate the individual policy teams to keep with the leaders, and a national research conference to clarify new standards of performance and means of meeting them. A successful prototype will diffuse only so far as it makes sense to decision makers in other communities.

Politics. This decentralized approach based on modest prototypes also facilitates the search for political consensus. First, the decentralization of decisions multiplies the number of opportunities to achieve a political consensus on innovative proposals. An innovative action proposal that is politically unimportant or infeasible in Washington need not be deferred; it can be put on the public agenda elsewhere in the nation through local leadership. Second, a modest proposal can minimize local opposition and uncertainties that might otherwise exacerbate fears of innovation and change. Compared to comprehensive national plans, a modest proposal affects fewer interests over shorter periods of time, the impacts are more transparent, and any adverse impacts are more likely to result in termination because fewer resources are committed. Third, the implementation of a modest but controversial innovation stimulates the reestablishment of consensus on the basis of experience. The proponents are motivated to demonstrate that it performs as promised, while the opponents are motivated to demonstrate that it does not; and feedback is often sufficiently quick and direct to compel one side or the other to acknowledge that it had been mistaken. The reestablishment of consensus is an important factor in reducing opposition to the diffusion of a successful prototype to other communities.

For example, in Davis, the building contractors who unsuccessfully opposed the passive solar code subsequently endorsed it in Congressional hearings as an effective means of reducing energy costs with no increase in construction costs. One contractor was not convinced until he put thermometers in units he had built under the old and new building codes, and observed a substantial temperature difference on a hot summer day [Subcommittee on Energy and Power, 1979; Brunner, 1980]. In Seattle, opponents of the City Council's decision moderated their opposition when the initial results of the city's conservation and efficiency programs exceeded expectations and endorsed the process by which the decision was made, if not the decision itself, in Congressional hearings [Subcommittee on Energy and Power, 1979; Brunner, 1980]. The Council's decision was reinforced in 1983, when WPPSS defaulted on $2 billion in bonds to construct two canceled nuclear reactors. Similarly, in Wisconsin, the chief planner for the largest state's largest utility unsuccessfully fought the mandate of least-cost alternatives, but subsequently endorsed the mandate as a means of reducing risk in an uncertain business climate [Porter, 1987]. Note that such innovations -- a passive solar building code, a decision against nuclear power, or a mandate for least-cost alternatives to meet new electricity demands -- have not been high on the federal policy agenda. In connection with the Seattle controversy in 1976, the Chairman of the Citizens' Overview Committee testified that "The [Department of Energy] regional office, of course, would not touch the policy questions that we were addressing with a ten-foot pole" [Brunner, 1980, 84].

Finally, the decentralization of decisions leaves scientific and other policy experts more accountable to the general public. The direct observations and personal experience of the ordinary citizen are concentrated in the local community. Such local knowledge can be used to assess the claims of competing experts, and it is likely to be used when issues are opened up at the local level. From the standpoint of the ordinary citizen, the resolution of a local issue has relatively immediate impacts, and the possibility of making a difference in city hall or the county building is typically greater than in Washington or an international organization. Moreover, the expert who fails to take local knowledge and preferences into account on local issues is at a disadvantage in the competition for public support. On national and international issues of long duration, the debate is more likely to take place among the experts -- beyond the immediate interest, understanding, or influence of the ordinary citizen.

Program Questions

For purposes of evaluation, it is worthwhile to raise some questions about the main possibilities for failure of this modest program. Perhaps the main question is whether it can overcome the conventional presumption that large problems require one centralized, comprehensive policy solution. Senator Gore [1990, 124] illustrated this presumption in a 1990 proposal:

> The world is in the midst of an environmental crisis beyond anything yet experienced; unless radical steps are taken to safeguard the planet, our future on it cannot be secured. In response to the crisis, I propose that the U.S. launch a Strategic Environmental Initiative (SEI), similar in scope and funding to the Strategic Defense Initiative (SDI).

Such proposals resonate with collective memory of crises in which science-based technology provided the solution: The Manhattan Project developed the winning weapon in World War II, Project Apollo won the race to the moon during the cold war, and so, presumably, a Strategic Environmental Initiative can secure our future on an endangered planet. The simple formula is exemplified by President Kennedy's Apollo directive in 1961: The President commits the nation to a clear but profound goal, the political system provides resources commensurate with the challenge, and the scientists and engineers do the rest. The apparent justification of this approach depends more on its own scale than on historical facts or careful analysis: One centralized, comprehensive plan *appears* to affirm its own importance relative to multiple modest alternatives, and therefore to merit more widespread attention if not support.[19] A centralized, comprehensive plan also *appears* to affirm the wisdom and power of those few who are in a position to understand and control it.

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[19] On the expansion and contraction of claims in symbolic politics, see Lasswell and Kaplan [1950, 104-107].

Consideration of this modest program may depend upon conscious awareness of the conventional presumption and the arguments against it. One argument is that a centralized, comprehensive plan is not likely to be approved intact in an open political system in the absence of war, cold war, or equivalent crises; and that, in any case, the scale and attempted coordination of such a plan inhibit learning through trial and error -- a process that is unavoidable amidst significant scientific uncertainties, goal ambiguities, and political differences. In contrast, decentralized processes of trial and error can identify successful prototypes, and the diffusion, replication, and adaptation of successful prototypes can multiply the benefits rather quickly with little or no central direction.[20] Vice President Gore [1993] recognized elements of this evolutionary strategy in a proposal to decentralize government on the model of a massively parallel computer. Similarly, in his Inaugural Address, President Clinton drew attention to the "bold, persistent experimentation" of Franklin Roosevelt's New Deal, which included many failures as well as some successes. Among them was Social Security, initially a program of great ideological but modest practical significance.

Several other questions have an important bearing on the success or failure of this modest program, but cannot be answered reliably without the experience that would follow from implementation. First, to what extent can scientists, administrators, and elected officials in Washington reconcile and align their special interests with the legislated mandate they have used to justify the program? It is possible that special interests -- including funding research, sustaining agencies, and maintaining political constituencies -- can be realized as a consequence of meeting the program's primary goal, rather than as a substitute for it. Among other factors, performance as promised according to the program's legislated mandate could become an asset in the competition for authorizations and appropriations in the federal budget cycle. At least it is clear that shortfalls in performance became a political liability in the struggle to sustain other large programs, including the Superconducting SuperCollider and the Space Station. Moreover, the competition among surviving programs will increase so long as fiscal constraints, backed by massive federal deficits, operate selectively to terminate weaker programs. Nevertheless, business as usual is often preferred to change.

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[20] **The underlying metaphor is biological rather than mechanical. See, for example, Dyson [1989, 155]: "When I compare the biological world with the world of mechanical industry, I am impressed by the enormous superiority of the biological processes in speed, economy and flexibility."**

Second, to what extent can decentralized policy teams integrate results from many specialized areas of research with value preferences and practical insights from their various locales? It is possible that decentralized policy teams could recruit enough people with the ability to integrate specialized knowledge and information from various scientific and non-scientific sources. Over recent decades, some experts in the physical and natural sciences have begun to relate their specialized knowledge to policy problems, and complicated their careers accordingly. Moreover, about twenty-five years ago, major universities in the U.S. established a first generation of public policy schools to train specialists in the integration of knowledge for policy purposes. The policy schools typically justified themselves on grounds that no policy problem falls entirely within the scope of any one discipline, and that the traditional disciplines in any case tend to focus on problems of theory and method, not policy. Nevertheless, it is not clear how much progress has been made on the problem of integration for policy purposes [Rivlin, 1984].

Finally, to what extent will decision makers actually consider, accept, and implement recommendations from the policy teams, and therefore subject the recommendations to the test of experience? It is possible that enough decision makers will take action on enough of the recommendations of the policy teams to sustain the process of learning through trial and error. Nevertheless, decision makers may find those recommendations unintelligible, ill-advised, or insignificant compared to more pressing problems. Or they may find it expedient to avoid global change issues by substituting research for action. Such questions cannot be answered reliably without the experience that would follow from action on modest alternatives.

III. The Broader Context

The integration of science and policy in global change research is a problem that will be resolved in the broader context of science and technology policy in the U.S. That context has begun to change in response to many factors, including declining standards of living in the lower and middle classes, persistently high federal budget deficits and international trade deficits, and the end of the cold war. Change is manifest in growing demands that science and science-based technology serve the public good in more direct and demonstrable ways.

George E. Brown, Jr., as Chairman of the Committee on Science, Space, and Technology in the U.S. House of Representatives, took the lead in diagnosing the shortcomings of science and technology from the standpoint of society. His basic diagnosis is "the objectivity crisis," or the modern tendency to elevate science above "other types of understanding which are overtly and explicitly value based" [Brown, 1992a, 780].[21] Science alone cannot solve policy problems, he argues, despite the widespread "expectation that science will provide data that will dictate policy, or provide technology that will obviate the consequences of our past actions." Hence "science -- as articulated by scientists and policy-makers alike -- has promised much more than it can deliver."

> The very benefits that science promises to deliver may be withheld from us because it is easier -- politically, economically, socially, scientifically -- to support more research than it is to change ourselves. The promise of science -- a miracle cure -- serves the politicians, who are always looking for patent medicine to sell to the public, and it serves scientists, who understandably seek to preserve their special position in our culture. But it may not serve society as advertised. Indeed, the promise of science may be at the root of our problems.

Defining a more constructive role for science begins with consideration of basic social goals and leads to creation of "linkages between the search for scientific truth, and the desire to achieve justice in society."

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[21] The title stems from the writings of the Czech playwright and philosopher Vaclav Havel. Havel [1992] wrote that "The modern era has been dominated by the culminating belief...that the world...is a wholly knowable system governed by a finite number of universal laws that man can grasp and rationally direct for his own benefit." Compare the scientific presumption on which the USGCRP was founded.

What can be done toward this end? Brown [1992a, 781] insists that scientists must understand their own role in a changing society, and that society must define goals that provide an overall framework for scientific research. Within this context, "the scientific community must seek to establish a new contract with policy makers" based on implementation of a research agenda rooted in social goals rather than demands for autonomy and ever-increasing budgets. Accordingly,

> ...scientists and policy makers must work together to make certain that research programs stay focused on policy goals, that 'scientific excellence' defines a path for achieving these goals, rather than an excuse for political inaction, that success of research is measured by progress toward a better quality of life for humankind, rather than by number of publications or citations or research grants.

Finally, scientists can enrich the human spirit by sharing with others what they know and how they feel. "This demands a renewed commitment to education as the ultimate mechanism for individual empowerment, and a critical prerequisite for social justice" [Brown, 1992a, 781].

Global change research is a part of the objectivity crisis. In "Global Change and the New Definition of Progress," Brown [1992b, 19] observes that "Science cannot and does not exist in a moral vacuum."

> Scientists tell us their data are objective, unburdened by ethical and moral implications. That leaves us politicians free to apply the data in any way we see fit. And we do. Scientific uncertainty has become an operational synonym for inaction on global environmental issues, and the debate over global change has thus become an impediment to action on a wide range of issues critical to our survival.
>
> The immediate challenge for science and technology must not be viewed as the need to reduce scientific uncertainty about climate warming. This is a hollow ambition. It is too easy to support and too unlikely to bear fruit. The real challenge is to find ways to increase the quality of life of humankind

throughout the world today.

These views challenge the presumption that the reduction of scientific uncertainty is a prerequisite for policy action, and that adherence to scientific standards insulates science from moral and political questions.

Global change research could become a significant means of shaping a new social contract between science and society. The USGCRP's large scale and potential visibility are significant in this connection: The request for FY 1995, $1.8 billion, is on the same order of magnitude as the latest request for the Space Station and the last request for the Superconducting SuperCollider. Table I depicts one possible transition suggested by the recent addition of an integrated assessment function to the Program. From What? is a paradigm represented by a predictive model used for policy purposes. To What? is a paradigm represented by multiple modest alternatives. The two paradigms are distinguished according to their fundamental assumptions about science, rationality, and the consent of the governed -- all of which may be considered basic social goals. What these goals mean, and the means of realizing them, differ across the two paradigms; and these differences are barriers to communication across paradigms. The point of Table I is to stimulate conscious consideration of the effects of Program decisions on the social contract.

In any case, the social contract between scientists and policy makers worked out under the leadership of Vannevar Bush after World War II can no longer be taken for granted. As described by the OTA [1991, 4], "This social contract implied that in return for the privilege of receiving Federal support, the researcher was obligated to produce and share knowledge freely to benefit -- in mostly unspecified and long-term ways -- the public good." However, unspecified and long-term benefits no longer seem satisfactory. A report by distinguished scientists and engineers "recognizes society's concern that scientific and technological progress should demonstrably lead to improvements in the quality of life", but "proposes a renewed and strengthened covenant between science, technology, and society" rather than a new covenant [Committee on Science, Engineering, and Public Policy, 1993, vi]. Erich Bloch, a former director of the National Science Foundation, observes that "the days of Vannevar Bush are over

Table I

The Changing Social Contract: One Possible Transition

FROM WHAT?	TO WHAT?
A Predictive Model	**A Modest Alternative**
Science	
The purpose of science is to predict, with precision and accuracy, the consequences of a comprehensive range of possible changes in a system. Science can discover and use objective laws of nature for this purpose.	The purpose of science in human affairs is freedom through insight that brings more factors more reliably into conscious awareness for purposes of decision. Such freedom limits forecast accuracy.
Rationality	
Scientific predictions reduce uncertainty. Hence they are prerequisites to major policy decisions that are rational, comprehensive, and cost-effective with respect to fixed or given national goals.	Given uncertainty and ambiguity, it is more rational to field test multiple, discrete alternatives; to diffuse, replicate, and adapt the successes; and to allow for adjustments in goals as well as in alternatives.
Politics	
Political consensus depends upon objective scientific knowledge. Scientists deserve a privileged position above politics because their inputs to policy decisions are objective and value free.	Political consensus depends on trust and credibility derived from experience. The promises and performance of scientists, like other participants in politics, are subject to public accountability.

and goné....The whole world is changing....It's time to reinvent NSF" [Quoted in Marshall, 1993, 1513]. Whatever the eventual outcome, change in the broader context brings uncertainty and ambiguity to the future of global change research.

CONCLUSION

The integration of science and policy in global change research remains problematic several years after the USGCRP acquired a policy mandate. What are the implications for those with an investment in the future of global change research?

First, the policy mandate should be taken seriously for both principled and prudent reasons. In a government of laws, there is an obligation to respect the law as a working specification of the public interest. If the policy mandate in P.L. 101-606 is burdensome to global change researchers and administrators, the appropriate response is to work through the legislative process to remove the policy mandate and to rejustify USGCRP on scientific grounds alone. The inappropriate response is to discount the mandate as a convenient fiction to fund more scientific research, as if the end justified the means. That would further undermine trust in scientists and their credibility [Roberts, 1991; Bernabo, 1991; Brunner, 1993], and leave the public unprepared to cope with global change. Moreover, long-term funding for global change research depends on renewing trust through relatively specific, short-term benefits consistent with the policy mandate. For elected representatives of the public, an investment in global change research is not an end in itself but a means of advancing social goals. It is doubtful they will sustain that investment over many years on faith alone -- especially as growing entitlement costs collide with continuing efforts to reduce federal budget deficits and avoid tax increases.

Second, a significant barrier to the realization of relatively specific, short-term benefits consistent with the policy mandate is the presumption on which the Program was established. The presumption is that the prerequisite for rational, comprehensive and cost-effective policy responses is the reduction of scientific uncertainty through comprehensive predictive models. That presumption appears to uphold scientific standards by insulating scientific research from moral and political considerations, and, at the same time, to support the privileged position of global change research in the competition for public funds. That presumption more realistically inhibits the effective integration of scientific and non-scientific considerations for policy and social purposes, and undermines the long-term position of global change research. Finally, that presumption represents a paradigm that is obsolescing under the pressure of increasing demands that science and science-based technology serve the public good in more direct and demonstrable ways.

Third, multiple modest alternatives to comprehensive predictive models can realize relatively specific, short-term benefits consistent with the policy mandate. Through modest alternatives we can more quickly and reliably address the scientific uncertainties, moral ambiguities, and political differences in multiple locales at the same time; and for each locale we can learn how to integrate what we find for purposes of action. From the alternatives selected by decision makers, we can distinguish what works from what does not on the basis of field experience, and we can evolve improvements in practical means for mitigating and adapting to global change. The criteria for assessing improvements might include demonstrated scientific capabilities, procedural rationality, and the consent of the governed, in addition to scientific standards of review.[22] Multiple modest alternatives, and a broader range of criteria, may represent the emerging paradigm.

Through progress consistent with the policy mandate we may eventually affirm that ecological activists had it right all along when they urged us to think globally, but act locally. The integration of scientific information into one image of the Earth as a whole makes sense for scientific purposes, and for the larger purpose of revising popular images of humanity's past and future on the planet [Rotmans, 1990, 7]. For purposes of guiding policy and action, however, the integration of specialized scientific, moral, and political information into multiple maps of limited scope -- each adapted to one part of the global problem and rather easily corrected --

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[22] This third implication may be considered a specific example of a general recommendation by Clark and Majone [1985, 17]: "A priority goal should...be the exploration of new institutional mechanisms for critical appraisal and evaluation of scientific inquiry in policy contexts. At least in its early states, this exploration should be frankly experimental, adopting a variety of mechanisms in actual problem contexts and assessing the results."

appears to be more consistent with basic social goals.

In broader context, it seems that recent developments in U.S. science and technology policy, including global change research, were anticipated nearly three decades ago by the physicist Alvin Weinberg [1967, 83-84]:

> It is quite conceivable that our society will tire of devoting so much of its wealth to science, especially if the implied promises held out when big projects are launched do not materialize... It is as much out of a prudent concern for their own survival, as for any loftier motive that scientists must acquire the habit of scrutinizing what they do from a broader point of view than has been their custom.

That broader point of view goes beyond the next appropriation to the conditions necessary for maintaining long-term support; beyond science to the moral and political considerations necessary to make productive use of science for policy and social purposes; and beyond the obsolescing paradigm to other basic conceptions of the fundamental relationships between science and policy. In the transition to that broader point of view, the elite of global change research might choose to take the lead.

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References

Ascher, W., 1978, *Forecasting: An Appraisal for Policy Makers and Planners*, Johns Hopkins University Press, Baltimore.

Ascher, W., 1981, "The Forecasting Potential of Complex Models," *Policy Sciences* **13**, 247-267.

Ascher, W., 1982, "Political Forecasting: The Missing Link," *Journal of Forecasting* **1**, 227-239.

Bernabo, J., 1991, Letter to *Science* **251** (14 June), 1475.

Brown, G. E. Jr., 1992a, "The Objectivity Crisis," *American Journal of Physics* **60** (September), 779-781.

Brown, G. E., Jr., 1992b, "Global Change and the New Definition of Progress," *Geotimes* (June), 19-21.

Brunner, R. D., 1980, "Decentralized Energy Policies," *Public Policy* **28** (Winter), 71-91.

Brunner, R. D., 1986, "Case-Wise Policy Analysis: Redefining Policy," *Policy Sciences* **19**, 201-223.

Brunner, R. D., 1991, "Global Climate Change: Defining the Policy Problem," *Policy Sciences* **24**, 291-311.

Brunner, R. D., 1992, "Performance as Promised: Restructuring the U.S. Civil Space Programme, *Space Policy* **8** (May), 116-136.

Brunner, R. D., 1993, "Myths, Scientific and Political," in *The Objectivity Crisis: Rethinking the Role of Science in Society*, Chairman's Report to the Committee on Space, Science, and Technology, U.S. House of Representatives (June), Government Printing Office, Washington, DC, 6-12.

Carter, J. E., 1977, "The Energy Problem," The President's Address to the Nation, in *Weekly Compilation of Presidential Documents* **13** (April 18), 560.

Clark, W. C., and Majone, G., 1985, "The Critical Appraisal of Scientific Inquiries with Policy Implications," *Science, Technology, & Human Values* **10** (Summer), 6-19.

Collingridge, D., 1992, *The Management of Scale: Big Organizations, Big Problems, Big Mistakes*, Routledge, London.

Committee on Earth and Environmental Sciences, 1992, *Economics and Global Change: The FY 1993 Research Program on the Economics of Global Change* (A Supplement to the U.S. President's FY 1993 Budget).

Committee on Earth Sciences, 1989, *Our Changing Planet: The FY 1990 Research Plan* (A Report by the Committee on Earth Sciences, July).

Committee on Earth Sciences, 1990, *Our Changing Planet: The FY 1991 U.S. Global Change Research Program* (A Supplement to the U.S. President's Fiscal Year 1991 Budget).

Committee on Environment and Natural Resources Research, 1994, *Our Changing Planet: The FY 1995 U.S. Global Change Research Program* (A Supplement to the President's Fiscal Year 1995 Budget).

Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 1993, *Science, Technology, and the Federal Government: National Goals for a New Era*, National Academy Press, Washington, DC.

Committee on the Human Dimensions of Global Change, Commission on Behavioral and Social Sciences and Education, National Research Council, 1994, *Memoranda from a Workshop on Research Needs and Modes of Support for the Human Dimensions of Global Change* (July), National Research Council, Washington, DC.

Committee on Science, Space, and Technology, U.S. House of Representatives, 1993, *Hearings on Global Change Research: Science and Policy* (May 19, 1993), Government Printing Office, Washington, DC.

Committee on Science, Space, and Technology, U.S. House of Representatives, 1994, *Hearings on Climate Change Action Plan and Assessment* (November 16, 1993), Government Printing Office, Washington, DC.

Commoner, B., 1979, *The Politics of Energy*, Knopf, New York.

Dyson, F., 1989, *Infinite in All Directions*, Harper & Row, New York.

Earth System Sciences Committee, NASA Advisory Council, 1986, *Earth System Science Overview: A Program for Global Change* (May), NASA, Washington, DC.

The Economist, 1994, "A Problem as Big as a Planet," *The Economist* (November 5), 83-85.

Energy Policy and Planning Staff, Executive Office of the President, 1977, *The National Energy*

Plan, Government Printing Office, Washington, DC.

Glantz, M. H. (ed.), 1988, *Societal Responses to Regional Climatic Change: Forecasting by Analogy*, Westview Press, Boulder, CO.

Glieck, J., 1987, *Chaos: Making a New Science*, Penguin, New York.

Gore, A., 1990, "A New Initiative to Save the Planet," *Scientific American* (April), 124.

Gore, A., 1993, "This Time We Mean Business: Vice President Gore Says Government Can and Will Do Better," *Washington Post National Weekly Edition* (September 20), 25.

Havel, V., 1992, "The End of the Modern Era," *New York Times* (March 1), Sec. 4, 15.

Hogarth, R. M., 1981, "Beyond Discrete Biases: Functional and Dysfunctional Aspects of Judgmental Heuristics," *Psychology Bulletin* **90**, 197-219.

Iott, S. E., 1992a, "The Energy Precedent," in *Final Report: Research in Geosciences Policy*, NASA Grant NAGW-1415, Center for Public Policy Research, Boulder, CO.

Iott, S. E., 1992b, *Decentralized Electricity Policy: A Federal Role*, M.A. Thesis, University of Colorado, Boulder.

Kaplan, A., 1963, *American Ethics and Public Policy*, Oxford University Press, New York.

Keepin, B., 1984, "A Technical Appraisal of the IIASA Energy Scenarios," *Policy Sciences* **17**, 199-275.

Keepin, B., 1986, "Review of Global Energy and Carbon Dioxide Projections," *Annual Review of Energy* **11**, 357-392.

Keepin, B., and Wynne, B., 1984, "Technical Analysis of IIASA Energy Scenarios," *Nature* **312** (December 20/27), 691-695.

Lasswell, H. D., 1951, "Democratic Character," in *The Political Writings of Harold D. Lasswell*, Free Press, Glencoe, IL, 465-525.

Lasswell, H. D., 1965, "The World Revolution of Our Time: A Framework for Basic Policy Research," in H. D. Lasswell and D. Lerner (eds.), *World Revolutionary Elites*, M.I.T. Press, Cambridge, 29-96.

Lasswell, H. D., 1971, "The Problem Orientation," in *A Pre-View of Policy Sciences*, Elsevier, New York, Ch. 3.

Lasswell, H. D., and Kaplan, A., 1950, *Power and Society*, Yale University Press, New Haven.

Malabre, A. L., Jr., and Clark, L. H., Jr., 1989, "Dismal Record: Changes in Economy Cause

Much Confusion Among Economists," *Wall Street Journal* (March 27), 1.

March, J. G., 1982, "Theories of Choice and Making Decisions," *Society* (November/December), 29-39.

Marshall, E., 1993, "Senate Turns Up the Heat on NSF," *Science* **261** (17 September), 1512-1513.

Miller, A., Mintzer, I., and Brown, P. G., 1990, "Rethinking the Economics of Global Warming," *Issues in Science and Technology* (Fall), 70-73.

Monastersky, R., 1993, "The $1.5 Billion Question: Can the U.S. Global Change Research Program Deliver on Its Promises?" *Science News* **144** (September 4), 158-159.

Munts, M. L., 1987, "Regulatory Monitoring of Electric Capacity Planning: An Assessment of Wisconsin's Experience," Presented at the Retrospective Conference on Energy/Environment Management, International Institute for Applied Systems Analysis, Laxenburg, Austria (June 24).

Office of Management and Budget, 1991, *Budget of the United States Government for Fiscal Year 1992*, Part Two, Government Printing Office, Washington, DC.

Office of Technology Assessment, 1991, *Federally Funded Research: Decisions for a Decade*, OTA-SET-490, Government Printing Office, Washington, DC.

Office of Technology Assessment, 1993a, *Preparing for an Uncertain Climate -- Volume I*, OTA-O-567, Government Printing Office, Washington, DC (October).

Office of Technology Assessment, 1993b, *Global Change Research and NASA's Earth Observing System*, OTA-BP-ISC-122, Government Printing Office, Washington, DC (November).

Oreskes, N., Shrader-Frechette, K., and Belitz, K., 1994, "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences," *Science* **263** (4 February), 641-646.

Pielke, R. A. Jr. (1994), *Completing the Circle: Global Change Science and Usable Policy Information*, Ph.D. Dissertation, University of Colorado, Boulder.

Porter, D. K., 1987, "The Status of Energy Strategies in the State of Wisconsin," Presented at the Retrospective Conference on Energy/Environment Management, International Institute for Applied Systems Analysis, Laxenburg, Austria (June 24).

Rayner, S. (1993), "National Case Studies of Institutional Capabilities to Implement Greenhouse

Gas Reductions: Introduction," *Global Environmental Change* **3** (March), 7-11.

Rivlin, A. M., 1984, "A Public Policy Paradox," *Journal of Policy Analysis and Management* **4**, 17-22.

Roberts, L., 1991, "Learning from an Acid Rain Program," *Science* **251** (15 March), 1302-1305.

Rotmans, J., 1990, *IMAGE: An Integrated Model to Assess the Greenhouse Effect*, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Schlesinger, J. R., 1968, "Systems Analysis and the Policy Process," *Journal of Law and Economics* (October), 281-298.

Simon, H. A., 1983, *Reason in Human Affairs*, Stanford University Press, Stanford, CA.

Sokal, R. R., 1974, "Classification: Purposes, Principles, Progress, Prospects," *Science* **185** (27 September), 1115-1123.

Starobin, P., 1993, "Trouble in the Temple," *National Journal* (May 29), 1278-1281.

Subcommittee on Energy and Power, Committee on Interstate and Foreign Commerce, U.S. House of Representatives, 1979, *Hearings on Local Energy Policies* (May 22, June 5, 9), Serial No. 95-135, Government Printing Office, Washington, DC.

Sylvester, K., 1990, "Global Warming: The Answers Are Not Always Global," *Governing* (April), 42-48.

Trevor-Roper, H. R., 1980, *History and Imagination*, Clarendon Press, Oxford.

Weinberg, A., 1967, *Reflections on Big Science*, M.I.T. Press, Cambridge.

THE NEW NATIONAL WIND TUNNEL COMPLEX

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Introduction

Research, development, and operational facilities are critical to maintaining U.S. leadership in aerospace technologies. Recognizing their importance, National Aeronautics and Space Administration (NASA) Administrator Daniel Goldin initiated development of a comprehensive long-term plan for the nation's aerospace facilities. In early 1993, the National Facilities Study Team was established as an interagency group to study current U.S. aeronautical and space facilities and formulate a national plan to improve American aerospace competitiveness. Participants included NASA, the Department of Commerce, the Department of Defense, the Department of Energy, the Department of Transportation, and representatives from industry. The aeronautics portion of their report, the National Facility Study (NFS), was completed in April, 1994. Its central recommendation was to develop a new national wind tunnel complex (NWTC) consisting of one transonic and one subsonic wind tunnel.

This facility would supplement the existing research-oriented NASA wind tunnels in meeting the needs of the U.S. aerospace industry to develop and design advanced, efficient aircraft. In contrast to research tunnels, whose design is driven by requirements associated with the collection of scientific data from one-of-a-kind tests, development tunnels are designed and built to minimize cycle times and costs, so that industry can bring new aircraft to market more quickly and at a lower cost than the competition. Development tunnel design therefore emphasizes not just aerodynamic capability (e.g., high Reynolds number and flow quality) but also high productivity and low operating cost. The proposed national wind tunnel complex would meet these needs.

Funding of the NWTC may also be done differently than it has been in the past. Although no firm proposal has yet emerged, it is thought that the NWTC will be designed, built, and financed by a joint government-industry consortium. Significant barriers to this innovative approach, however, would have to be overcome. The cost of the facility, for example, has yet to be determined and will be strongly affected by the highly charged political hurdle of site selection. Another uncertainty is the size of the investment government and industry can afford.

Proposed National Wind Tunnel Complex

Technical Benefits

The proposed NWTC can effect incremental increases in the economic competitiveness of commercial aircraft by enabling technological advances that increase lift and reduce drag and weight, and by improving our ability to estimate aircraft performance in advance of first flight.

The value of the new complex lies in the capability to test models under simultaneous Reynolds number and Mach number conditions close to those experienced in flight. These two parameters permit predictions of full-scale flight vehicle performance through the use of simulated, subscale wind-tunnel models; that is, the closer the wind-tunnel Mach and Reynolds numbers are to those that will actually be encountered by the operational aircraft, the better the simulation of the aircraft's flight characteristics will be.

The flight Mach number is not hard to match, but it is technologically difficult and expensive to build facilities capable of testing large aircraft at — or close to — the full flight Reynolds number (a dimensionless parameter defined as the product of flight velocity, air density, and characteristic aircraft dimension, divided by the air's viscosity). Instead, most wind-tunnel testing is performed at lower Reynolds numbers, forcing engineers to extrapolate their data to the flight condition. The inherent uncertainty of this extrapolation requires aircraft design and performance estimates to be over conservative, precluding industry from utilizing the full value of their aircraft. It should be noted that manufacturers must guarantee performance prior to completing the aircraft design. High Reynolds number testing will reduce the uncertainty and thereby decrease design conservatism.

Transonic Wind Tunnel

The transonic wind tunnel (TSWT) would offer a maximum Reynolds number of 28.2 million[1] in an 11.5-ft by 15-ft test section, and would assist in the optimization of aircraft for cruise and other transonic flight conditions. The transonic tunnel will provide the largest overall benefit. Approximately 90% of the flight time for a subsonic transport is in transonic cruise (Mach number 0.75 to 0.9),[2] and reductions in cruise drag significantly decrease aircraft fuel consumption. This increases aircraft range and/or decreases fuel burn, reducing operational costs.

These benefits would be achieved by using the TSWT and its high Reynolds number capability in the high-speed design process. After an initial cruise wing design has been formulated using computational fluid dynamics (CFD), it is tested in a wind tunnel to verify that performance objectives have been met. The wind tunnel data may identify shortcomings in the design, so that engineers can redesign the wing for better performance using CFD techniques.[3] The pressure distribution and the location of the shock wave on the upper surface of the wing can be tailored to minimize flow separation and decrease drag. The high Reynolds number capability of the new TSWT will provide improvements in modeling accuracy, allowing designers to better optimize their designs.

The TSWT will also provide more accurate data on stability and control characteristics and aerodynamic loads for flight at both cruise and transonic off-design conditions. The stability and control data are used to size control surfaces[4] and the actuators which drive them, while loads data are utilized to design structural members. Improvements in the accuracy of flight simulation can reduce the size and weight of these components by reducing the conservatism in their design. Reductions in drag can result, but the weight reduction is the most significant. Decreasing the empty weight of an aircraft increases its payload and range and/or reduces its fuel consumption and thrust requirements over its entire operational lifetime.

Subsonic Wind Tunnel

The subsonic wind tunnel (or Low-Speed Wind Tunnel, LSWT) complements the design process with the low-speed, high-lift testing capability needed to model take-off and landing. The advertised maximum full-span Reynolds number of 20.4 million[5] is a large improvement over existing test facilities and would address the present need to test near flight Reynolds number. Unlike that of the cruise condition, the fundamental physics of the highly complex flows associated with high-lift devices such as leading-edge slats and multipiece flaps are not as well understood. Furthermore, phenomena known as "re-

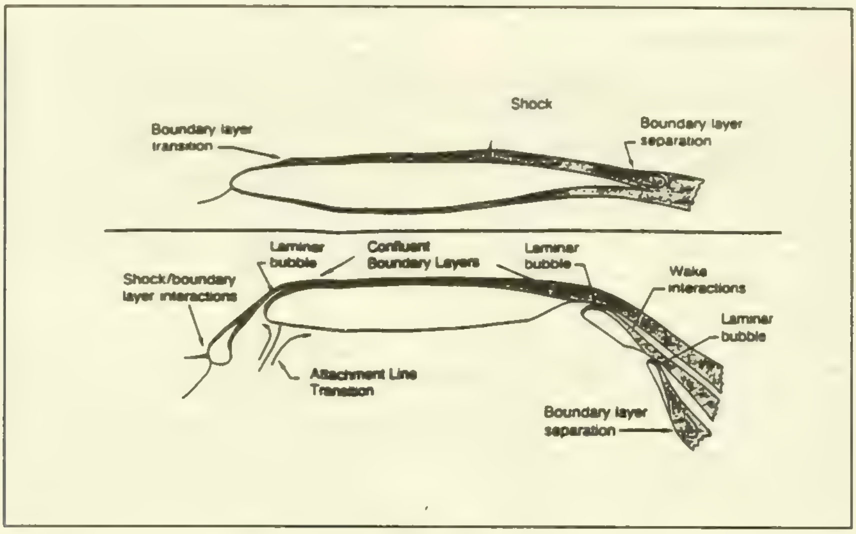
Shock
Boundary layer transition
Boundary layer separation
Laminar bubble
Confluent Boundary Layers
Laminar bubble
Shock/boundary layer interactions
Wake interactions
Laminar bubble
Attachment Line Transition
Boundary layer separation

Figure 1
(Source: Mack, M.D. and J.H. McMasters, High Reynolds Number Testing in Support of Transport Airplane Development.)

verse Reynolds number" effects makes the extrapolation of results from experimental data obtained in existing lower Reynolds number facilities to the full Reynolds number condition highly problematic. The LSWT will address both of these considerations by providing high Reynolds number testing capability for low-speed, high-lift configurations. Improvements in the accuracy of simulating high-lift flight conditions could enable engineers to design and build more productive and perhaps less complex high-lift systems, reducing aircraft size and weight, cutting engine size, decreasing aircraft cost, and reducing operations and maintenance costs.

Figure 1 illustrates the geometric complexities of a high-lift configuration with deployed slat and flaps as compared to a cruise configuration. Multiple lifting elements yield complex and interdependent viscous compressible flows which are not fully understood. For a three-dimensional wing with sweep, the problem is exacerbated. As a result, the CFD tools presently available cannot be relied upon for detailed design alone; the wind tunnel is a critical tool in the high-lift design process.

For example, until the development of the Boeing 767 in the late 1970s, it was believed that aerodynamic performance always improved with increasing Reynolds number. Wind tunnel tests, however, revealed an unexpected drop in high-lift performance at moderate Reynolds numbers, as shown in Figure 2. Although this so-called "reverse Reynolds number effect" itself is reasonably well understood, its onset, and therefore its effect on the complex flows associated with high-lift systems, is not predictable. It is believed that the "Reynolds number effects on high-lift [systems] are correlated with flow transition and the boundary layer characteristics."[6]

The present inability to wind-tunnel test at high Reynolds numbers necessitates large extrapolation of test data to the flight condition. Figure 2 illustrates how this extrapolation (the dashed line in the figure) fails to predict lift loss at high Reynolds numbers due to the reverse Reynolds number effect. If testing is done beyond the transition Reynolds number, however, the data can be extrapolated to flight conditions with less uncertainty. Nevertheless, our lack of understanding of this phenomenon suggests that tunnel data should be obtained at the full flight Reynolds number to obtain a minimal level of uncertainty.

The LSWT will provide the testing capability necessary to test small aircraft at flight Reynolds numbers with full-span models and intermediate-sized aircraft like the Boeing 737 with semi-span models. Larger aircraft will also benefit from this increased capability, because their design risk can be reduced significantly if models can be tested beyond the transition Reynolds number. Unfortunately, the transition point is highly dependent on the specific geometry and boundary layer contamination characteristics of the configuration and can vary significantly. If transition occurs beyond 35 million,[7] there will be considerable uncertainty in extrapolating LSWT data to flight conditions.

Performance Guarantees

In addition to their use in design, wind tunnel data are used to estimate aircraft performance.[8] Commercial airframers must contractually guarantee minimum performance levels to their customers long before the first aircraft is ever built, and aerodynamic measurements taken in the wind tunnel are used to determine the appropriate minimums. Overestimating performance, and the subsequent failure to meet guarantees, requires industry to make compensatory payments to the customer. Hence technical uncertainty in test data leads to con servative business guarantees. Underestimating performance, how-

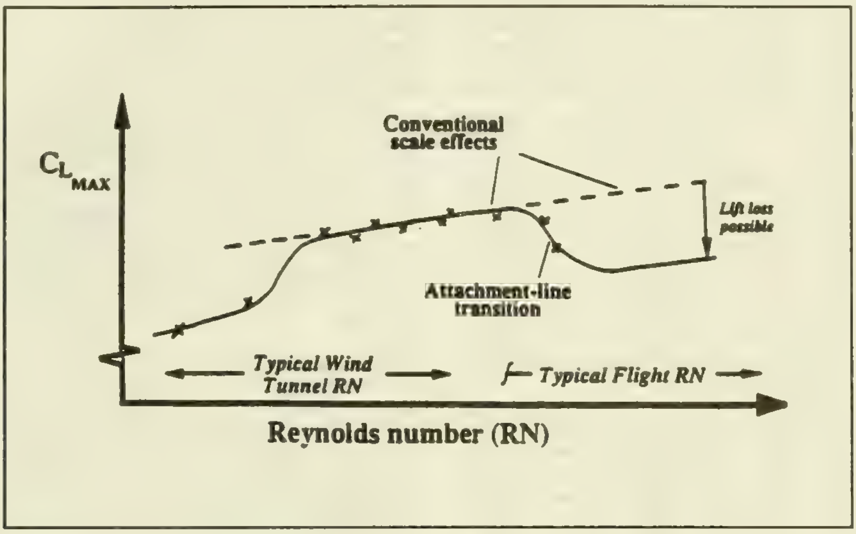

Figure 2
(Source: National Facility Study, Volume 2; New Subsonic and Transonic Wind Tunnel Complex.)

ever, is equally undesirable, because customers bid on and purchase aircraft according to guaranteed performance levels. Thus over conservative guarantees penalize the aircraft by making it less attractive compared to its competitors and by decreasing its value to the airline, thereby reducing the potential profitability of the design. The ability to make realistic, aggressive cruise performance guarantees is a compelling factor in the market-share equation.

Why Not Higher Reynolds Numbers?

The actual flight Reynolds number for a Boeing 747 in take-off and approach is about 40 million; during cruise it is about 60 million. Larger, future aircraft are likely to experience even greater flight Reynolds numbers. Why, then, build tunnels with maximum Reynolds numbers of only 30 million?

Admittedly, the difference between 30 million and 60 million at first appears quite substantial. The effect of Reynolds number on the aerodynamic properties of flight vehicles, however, is not a simple linear function. Considerable experimental experience suggests that the effects of Reynolds number scale according to its logarithm. The logarithms of 60 million and 30 million are 7.78 and 7.48 respectively, differing by less than 4%. Existing wind tunnels have Reynolds numbers near 10 million, so the difference in logarithms (from the desired 60 million) is about 11%. Hence in terms of the effects of Reynolds number, the new tunnels are much more accurate than existing tunnels. Also, it is not essential that the tunnels match the full flight Reynolds number for all aircraft. What is required is that the testing be done at a Reynolds number close enough to extrapolate the data to flight without significant uncertainties.

Transonic Wind Tunnel

Selection of the best wind-tunnel Reynolds number in the transonic regime is largely a matter of an educated opinion. The empirical data on this subject are not conclusive, and U.S. experts disagree on exactly how high the Reynolds number needs to be. The 30 million identified in the NFS emerged as an acceptable average of the opinions.

This value is not without empirical justification, however. Fundamental parameters such as skin friction drag and boundary layer displacement thickness tend not to vary very much between 30 million and 60 million. Thirty million is thought to correspond to the point at which the boundary layer flow is usually completely turbulent with transition located at the leading edge of the wing, so that extrapolation beyond that point is believed to entail minimal uncertainty.

Subsonic Wind Tunnel

As noted above, high-lift testing should ideally be done at the full flight Reynolds number because of the uncertainty associated with possible reverse Reynolds number effects. However, technological and economic constraints motivated the NFS to select 20.4 million (35 million for semi-span models) to provide a large benefit-to-cost ratio.

It was also noted earlier that a Reynolds number of 30 million is thought to be beyond the transition point for many aircraft and corresponds to the point where critical boundary layer characteristics appear to reach a plateau. It is therefore believed that the data collected at this Reynolds number can be extrapolated accurately to full scale.

The Reynolds number limit of the LSWT, however, introduces three concerns. The first relates to the flow over the smaller lifting elements in a high-lift system. The argument cited earlier for selecting Reynolds numbers around 30 million is that the flow will have stabilized enough to extrapolate the data to the flight condition. But for the flaps, slats, and other small surfaces this stable condition may not be reached even at full scale.

The size parameter generally used to compute the Reynolds number is the mean aerodynamic chord of the wing in the cruise configuration. Because the chords of high-lift devices are significantly smaller than that of the wing, the Reynolds number based on these chords is much lower, so the flow over these surfaces may not be as developed as that on the wing itself. Suppose, for example, that a flap's chord is 10% of the wing chord. If the flight Reynolds number (based on the wing chord) at Mach 0.3 is 60 million, the Reynolds number of the deployed flap would be 6 million, and a wind tunnel test performed at 30 million would yield a flap Reynolds number of only 3 million. But the boundary layer characteristics may not have stabilized between 3 million and 6 million, so the subsequent extrapolation could be inaccurate. This would mean that data from the LSWT may not be as valuable as predicted.

The second concern with the maximum LSWT Reynolds number (20.4 million, 35 million with semi-span models) is that it is based on a wind tunnel pressure of 5 atmospheres. Although the 12-ft NASA Ames tunnel operates at 5-6 atmospheres, the aerodynamic forces at these high pressures make it extremely difficult to build models for high-lift testing. The high-lift devices must be attached to the model with brackets that are small enough not to disturb the airflow, yet large and strong enough to withstand the loads without bending or breaking. Beyond three or four atmospheres it is difficult to build brackets for high-lift models that can withstand the loads and are not too big. Although industry has built and tested models able to withstand 5 atmospheres, this ability has yet to be demonstrated for the as-yet undefined LSWT test section. Reduced pressure capability would reduce the LSWT's Reynolds number. Related issues are the as-yet unknown effects of wall interference and model sting stiffness; should either of these turn out to be a problem smaller models would have to be used, further reducing the effective Reynolds number.

The third and final concern is that should the Reynolds number goal selected for the LSWT prove insufficient for any reason, increasing its capability will incur high costs unless planned for in advance. The LSWT is believed to be near the practical operational limit for a conventional pressurized tunnel, as noted earlier. The NFS notes that increasing the size of the test section, cooling the flow, or using a heavy gas as the test medium[9] could conceivably increase the Reynolds number, but each of these "fixes" would significantly increase the cost of the facility, decrease its productivity, and increase operating costs.

What about Computational Fluid Dynamics (CFD)?

CFD has made considerable progress in recent years and is now able to predict some fluid flows accurately enough for its use as the basis for final design decisions. However, CFD has limitations both in its practical utilization and in its capability that prevent its use as a replacement for wind tunnel testing. CFD simply cannot provide industry with the same type of data that the NWTC can generate.

Indeed, CFD and wind tunnel testing are complementary resources. CFD is usually able to generate data rapidly for a relatively small number of simulations at a cost much lower than that of a wind tunnel test. Tunnel tests are not only costly, but often require months of lead time. This investment of time and resources, however, is balanced by the large amount of data that can be obtained in the wind tunnel. Once a model is in the tunnel it is a simple matter to test it at numerous flight conditions. The tunnel Mach number, pressure, model orientation, and configuration (control surface deflections, for example) can be adjusted rapidly and cheaply to obtain a comprehensive aerodynamic characterization of the configuration over a wide spectrum of simulated velocities and altitudes. It is simply not feasible to utilize CFD to generate the same volume of data. CFD is best used strategically for analysis and design in limited but critical regions of the flight envelope, and in early advanced design to narrow the range of configurations that need to be tested in the wind tunnel.

Furthermore the capability of CFD to predict drag and highly complex flows accurately is still limited. The fundamental physics of complex flows with confluent boundary layer interactions, relaminarization, massive separation, and strong shocks are not completely understood. Additionally, the current turbulence models used in CFD are essentially mathematical correlations obtained from test data at lower Reynolds numbers. As a result, the complexities of high-lift systems, off-design transonic flight, and accurate drag prediction cannot yet be adequately modeled with CFD. Wind tunnel tests (as well as flight tests) remain the sole source of usable data on such flows, and high Reynolds number testing can provide significant advances in their predictive accuracy. Note, however, that it is not necessary to conduct all testing at high Reynolds numbers, even with the new facilities. Configurations need to be evaluated for Reynolds-number sensitivity, because testing at lower Reynolds numbers (and thus lower pressure) is more productive.

Some argue that funds invested in wind tunnels could be better used to understand the fundamental fluid physics which underlie these complexities and thereby enable advances in CFD modeling. Clearly, investments in fundamental research are critical in continuing to advance our understanding of aerodynamics and improvements in CFD, and as such are important in their own right. But this is a long-term investment which does not address either the present need for capability or the complementary relationship of wind tunnels and CFD in the design process.

Existing Wind Tunnels

Existing tunnels, both in the U.S. and overseas, do not meet the performance goals of the NWTC. Although some transonic wind tunnels do meet or exceed the Reynolds number requirement of the proposed TSWT, none do so at comparable cost and productivity. Similarly, the productivity and operating cost of the LSWT are superior to those of existing tunnels and its Reynolds number capability is significantly greater.

The table on the next page shows the core facilities used for U.S. aircraft development, as compiled by government and industry experts. The proposed LSWT and TSWT are included for comparison. Facilities are listed according to Reynolds number.

Facility	Reynolds No. (millions)[a]	Productivity (polars / hour)[b]	User Cost ($ / polar)	Age (years)[c]
Subsonic Tunnels				
LSWT (Proposed)	***20.4***	***5.00***	***752[d]***	***N/A***
NASA-ARC 40x80-ft	16.6	0.34	5965	51
NASA-ARC 80x120-ft	10.8	0.34	5865	11.5
DRA 5-m (Britain)	7.7	1.50	3000	16
NASA-ARC 12-ft[1]	7.6- 9.5[e]	2.85	1300	Rebuilt[f]
ONERA F-1 (France)	7.5	1.70	3000	17
Lockheed 16x20-ft	3.9	3.50	225	29
DNW (Netherlands)	3.6	4.00	1000	14
NASA-LaRC 14x22-ft	3.2	0.60	1050	24
Lockheed 8x12-ft	2.5	4.00	250	47
Transonic Tunnels				
NASA-LaRC NTF, Nitrogen	119.0	0.36	14300	11
ETW (Europe)	50.0	1.50	5600	0
TSWT (Proposed)	***28.1***	***8.00***	***644[d]***	***N/A***
NASA-LaRC TDT	16.0	0.20	5000	36
NASA-ARC 11-ft	10.3	4.00	1172	39
Calspan 8-ft	10.0	4.00	825	48
AEDC 16T	9.6	4.50	1170	38
Russian T-128	9.2[g]	1.00	2750	10
Rockwell 7-ft	7.0	2.00	1500	36
NASA-LaRC NTF, Air	6.0	2.00	1537	11
Boeing TWT	3.9	4.50	725	41

[1] The Ames 12-ft tunnel has been demolished and reconstructed. The new tunnel will have a maximum pressure capability of 6 atmospheres which will yield a Reynolds number of 12 million /ft at Mach 0.3. Additionally, the new control system and test section design will assist in attaining a 4 polar / occupancy hour productivity goal for the new facility.

Sources: National Facility Study, Volume 2; New Subsonic and Transonic Wind Tunnel Complex; personal communications.

[a] Reynolds number is calculated at different Mach numbers (0.25 to 0.35) for the subsonic tunnels and at Mach 1.0 for all transonic tunnels. The reference chord used equals 1/10 the square root of the test section cross-sectional area.

[b] Productivity and user cost are measured in terms of polars. As defined in the NFS and as used here, a polar is a set of "25 [test] data points, each point being obtained at a single value of an independent variable." Usually this independent variable measures the orientation of the model in the flow (e.g. angle-of-attack, flap setting, etc.).

[c] Facility age is as of 1994.

[d] Costs for the TSWT and LSWT are the estimated facility operational costs per polar, not the cost to the user. The projected user costs will be greater than these estimations.

[e] The Reynolds number of 7.6 million corresponds to a total pressure of 4 atmospheres, although the Ames 12-ft tunnel has a 6 atmosphere pressure shell, because the lower pressure may more accurately reflect both model load limitations and the pressures currently used in high-lift tests, as discussed previously. To directly compare the Ames 12-ft tunnel to the Re given for the LSWT, the 5-atmosphere Re (9.5 million) should be used.

[f] The NASA Ames 12-ft tunnel was over 40 years old in 1988 when it underwent reconstruction. It is scheduled to become operational in September 1995.

[g] Reynolds number is 9.2 million/feet at 0.8 Mach.

Currently, the European DRA 5-m and ONERA F-1 wind tunnels are the subsonic tunnels of choice for industry, at least until the NASA Ames 12-foot tunnel comes back on line. Since the demolition and reconstruction of the NASA Ames 12-ft tunnel began in 1988, U.S. industry out of necessity has utilized these European facilities to do much of their low-speed testing. Whereas the Reynolds number capability of the 40x80-ft and 80x120-ft tunnels at NASA Ames may appear to make them likely candidates for development testing, their large size and low productivity, which translates to high cost per polar, make them unsuitable for use in commercial fixed-wing development.[10]

The NASA Ames 11-ft and AEDC 16T transonic tunnels are currently used by U.S. industry for high-speed testing, but the capability of the recently completed European Transonic Wind Tunnel (ETW) may force the companies to test their high-speed configurations abroad. Both the National Transonic Facility (NTF) at NASA Langley and the ETW are cryogenic[11] tunnels, but the model handling and preparation facilities at the ETW enable it to achieve a much higher productivity than the NTF. The proposed TSWT, which achieves a moderately high Reynolds number through pressurization without cooling[12] and is designed to facilitate data acquisition, model handling, and model preparation, can yield much higher tunnel productivity than any cryogenic wind tunnel.

It is possible to make improvements in the productivity of existing tunnels with refurbishment and upgrades.[13] The model handling difficulties associated with cryogenic testing, however, will continue to significantly limit productivity gains for the NTF.

Furthermore, increases in the Reynolds number capability of existing facilities are limited by their pressure shells and drive systems. As noted above, the use of heavy gases can increase the Reynolds number, but its effect on the data is not fully understood. Even with such modifications the Reynolds number capability of existing facilities would still be far from the goals of the NWTC.

In short, modifications to existing U.S. facilities will not yield the unique combination of capability, productivity, and cost that the proposed NWTC is designed to provide.

Competitiveness

It is important to note that U.S. industry is currently using European facilities to meet its wind-tunnel testing requirements. Boeing does significant low-speed testing in Britain's DRA 5-m tunnel, while Douglas utilizes the French ONERA F-1 tunnel. Completion of the rebuilt NASA Ames 12-ft tunnel in 1995 will reduce this practice, but the new European Transonic Wind Tunnel (ETW) may draw even more testing abroad.

Access

Timely access to these facilities, though currently available, could be threatened in the future by the emergence of national programs whose scheduling priority would supersede American commercial development. This would severely impact the ability of U.S. industry to compete on a timely basis.

Government-Industry Relationships

U.S. commercial aircraft manufacturers compete directly with the Airbus consortium, but the relationship between government and industry is significantly different in the U.S. than it is in Europe. Unlike their American competitors, European manufacturers of civil aircraft and engines often receive government-sponsored loans to subsidize product research and development. Repayment of this "launch aid" is contingent on a predetermined level of the developed product's commercial success. Only after a specified number of aircraft or engines are sold do the companies begin to pay back the loans with a percentage of their profit from additional sales. This dramatically reduces the company's financial risk in developing new aircraft. A recent General Accounting Office (GAO) report stated that as of 1990 the French, German, and British governments had invested $13.5 billion in direct support of Airbus products. By August of 1993 the amount repaid was only $3.5 billion.[14]

U.S. industry must compete head-to-head with its European counterparts and develop new products without having the government reduce its financial risk. The development costs for new aircraft must be completely underwritten by industry, often resulting in "peak negative cash flows that can exceed the value of the company."[15] The development costs for the new Boeing 777 are estimated by *Aviation Week and Space Technology* to be in the $4 billion to $5 billion range. The business risk of such investments, when combined with payback periods approaching 15 years, puts U.S. industry at a distinct disadvantage relative to its foreign competitors.

In addition to launch aid, European governments provide major ground test facilities for their industry, much like NASA provides to U.S. industry. The construction of the recently completed ETW, for example, was completely funded by the governments of Britain, France, Germany, and the Netherlands, and operating-cost shortfalls are being covered by these governments until 1997. During the past 15 years six new wind tunnel facilities have been constructed in Europe[16] which take full advantage of recent technological advances. In contrast, nearly all the major U.S. wind tunnels used in commercial aircraft development have been in operation for over thirty years, with the major NASA wind tunnels ranging in age from 30 to 60 years old (average age: 38 years).[17] The demand for high Reynolds number, productive facilities did not exist when these U.S. facilities were built, and our present capability reflects this.

NASA's charter requires the agency to strive for preeminence in aviation. The proposed NWTC, if constructed, is an avenue by which the federal government could help the aerospace industry, as it has done in the past by building and operating the existing facilities, without providing a direct subsidy. The testing potential available with high Reynolds number facilities can reduce the financial risk inherent in the development of new designs and can assist the U.S. aerospace industry to maintain or improve its economic competitiveness in the global market. The global commercial aviation market is projected at just under a trillion dollars over the next two decades, and it is estimated that every dollar invested in U.S. commercial aircraft generates $2.30 in gross domestic product. Halting the erosion of U.S. market share is therefore increasingly important. The NWTC is one possible means to help halt that erosion.

Foreign Use of Tunnels

Whether or not Airbus and other foreign industries will have access to the NWTC has yet to be decided. As with American firms testing in foreign facilities, it is unlikely that foreign competitors will want to test in U.S. facilities unless forced to do so to remain competitive. U.S. industry today is forced to use European tunnels for testing that can't be accomplished in this country. The U.S. Department of Commerce plans not to deny Europeans access to U.S. wind tunnels, but it is possible that if foreign industry is allowed to capitalize on the capabilities of the NWTC, the competitive advantage of the wind tunnels to U.S. industry will be reduced.

Costs and Financing

The projected capital cost of the NWTC ranges from $3.2 billion to $2.5 billion or lower. The $3.2 billion estimate was based on the assumption that standard governmental acquisition procedures would be used to construct the facility. By using the best commercial practices this estimate was decreased to the current projection of $2.5 billion. These figures reflect the cost for the baseline facility,[18] but the final tunnel complex may differ somewhat. NASA's Wind Tunnel Program Office in Cleveland, Ohio, is continuing trade studies and cost-benefit analyses aimed at decreasing capital costs to a target of $2.0 billion.

Although the capital costs of projects like the NWTC have been historically funded by government alone, the government's current position is that this time industry should contribute to the capital cost of the complex. Funding approaches for the NWTC are currently being debated and innovative business arrangements investigated. The current fiscal environments for both the federal government and the aircraft industry constrain the funding options, but industry[19] has agreed in principle to participate in a consortium whose objective is an affordable design.

Discussions with NASA have suggested that a 90%:10%/government:industry share might be acceptable.[20] Others in the Administration and Congress, however, prefer a greater contribution by industry to the shared cost, believing that a higher level of financial commitment would tangibly demonstrate industry's need for the facilities. They question how great the need is if industry is willing to share in only 10% of its cost. Industry, on the other hand, asserts that the majority of the long-term, low rate-of-return investment required to fund the capital cost of the NWTC should not and cannot be made by the private sector. In the competitive and lean international aerospace market, they say, U.S. industry simply cannot justify even a $2.0 billion short-term cost to gain such very long-term benefits. Also, the need to amortize the cost of the facility would inflate the price of U.S. aircraft, making them less competitive in the marketplace and defeating the purpose of the NWTC.

User fees may be used to amortize some of the capital costs, depending on the operational costs and market price for wind tunnel testing. The estimated operational costs, however, are based on a series of assumptions including the national average for utility rates, wage rates, and a testing demand that equates to about two shifts of operation five days a week. The siting of the facility and other factors may change the current cost projections and make user fees an infeasible method of amortizing capital expenses, without sacrificing the fundamental NWTC motivation of providing low-cost development testing.

Financing options continue to be explored by joint industry-government teams, and their work will play a central role in deciding whether or not to construct the NWTC. One point of NASA-industry consensus that has already emerged is that funding for the wind tunnels should not come at the expense of the existing NASA aeronautics research and technology (R&T) base or High-Speed Research and Advanced Subsonic Technology aeronautics R&D programs. These programs are seen as critical to the future success of the national aeronautics enterprise and should not be sacrificed to build the facilities.

Siting — Schedule and Costs

The siting process for the NWTC will have a significant impact on the schedule, the facility's cost, and operating costs. The selection must be made by November 1996 or the NWTC schedule will slip, and the facility will not be operational by the 2002 target date. Roughly 70% of the design depends on site-specific considerations and cannot be completed until a siting decision has been made. Also, the site-specific Environmental Impact Statement required to construct the NWTC drives the program schedule and needs considerable lead time to perform.

The siting will also impact the operational cost of the facility. The local utility rates, for instance, can dramatically affect the facility's costs. The projection made in the NFS Report, based in part on experience with the NASA Ames 11-foot facility, assigns 35% to utilities, with 31% going to electricity alone.[21] This projection assumes the average national rates for electricity, water, and gas, but if the actual rates are higher at the selected site the operational cost projections could increase significantly. Labor, at 27%, is also a significant contributor to operational costs. Site selection also impacts capital costs; for example, in the size of cooling towers, weather protection, and seismic criteria.

The overall cost of the facility, however, will depend on the data presented when siting proposals are submitted. Utilities and labor rates will play a major role, but the combination package, which would include transportation costs, maintenance costs, constraints on critical subsystems, and state and local contributions, will determine the total facility cost at each candidate site.

Positions

The major parties involved in deciding whether or not to proceed with the construction of the NWTC approach the issue from different perspectives. Among the strongest supporters are the commercial airframe manufacturers, who face competitiveness obstacles if the tunnels are not built. The NWTC would provide them with a competitive edge in the world market by granting them access to facilities having the unique combination of capability, productivity, location, and cost that they need. Although the engine and military-aircraft manufacturers would also benefit from these tunnels, their support for the initiative has been less vigorous than that of the civil airframers.

In the Congress, there is general support for the aeronautics industry as a whole, stemming largely from its role as a significant positive contributor to the U.S. economy and balance of trade. Several members of Congress have expressed the desire to put the first "A" back in NASA, emphasizing the importance of "A"eronautics to the nation. Similarly, there is support for the concept of new national wind tunnels in the relevant committees, but agreeing on the details surrounding the NWTC will probably prove difficult. The House Subcommittee on Technology, Environment and Aviation (TEA) is generally in favor of the tunnels, but the issue of siting the facility has already emerged as a political issue. California, Tennessee, and Virginia are mobilizing to compete in the siting process and vie for the multi-billion dollar project.[22]

There also appears to be support for the wind tunnels in the Senate, but language in the Senate's FY 1995 appropriation bill (see below) further reveals the importance of site selection when it states that site selection "must ultimately be based on principles of cost." It also calls for the formulation of a budget plan in which industry will share up to 20% of the capital cost. In March 1994, Senators Rockefeller and Burns introduced S.1881, calling for a national aeronautical facilities strategy. Perhaps the most promising action was taken by the House and Senate Appropriations Committees in their August 1994 budget conference on the FY95 budget. They supported the Senate's insertion of $400 million in "new" FY95 funding toward NWTC construction, not requested by the Administration and, most important, not drawn from other NASA programs. The original Senate bill was characterized as a "use it or lose it pot" that could serve as a "down payment on the final completion of the project." The Senate intended that the appropriation elicit a "clear signal from the administration that they intend to proceed with [the wind tunnels]."

It is probable that the siting process will be subject to political pressures, especially with the 1996 national elections rapidly approaching.[23] Any decision which is not based on cost considerations, however, will inflate the price of the facility and its operating costs, and therefore will affect the financing options being investigated.

Aside from siting complications, the financing issue alone will be a difficult obstacle to overcome. The TEA subcommittee is "disappointed" with its perception of inadequate fiscal support from industry. The committee would like to see industry commit to more than the previously cited 10% of the capital costs of the program.

The Administration first became aware of the wind tunnel issue in the fall of 1993 during the budget preparation process for FY 1994. Because the information available at that time was insufficient to make a decision, it was deferred until the National Facility Study was completed. The President's decision may be revealed when his FY 1996 budget is released.

Concluding Thoughts

It is likely that the Administration's leadership will ultimately determine the success or failure of the wind tunnel initiative. The decision will be largely influenced by the final cost of the tunnels, the joint industry-government financing arrangements, and the politics of site selection. In today's tight fiscal environment, the future of the NWTC is still not clear.

But although the investment cost of the NWTC is considerable, the costs of not developing the facility must also be kept in mind. There is a historical link between technological infrastructure such as wind tunnels and technological advances in aviation. Foregoing the opportunity to develop innovative facilities will put the U.S. aerospace enterprise at a competitive disadvantage, eroding a major source of U.S. strength in the global marketplace and the jobs that go with it.

REFERENCES

Beach, H. Lee Jr. and John V. Bolino. *National Planning for Aeronautical Test Facilities*, AIAA 94-2474, June 1994.

Mack, M. D. and J. H. McMasters. *High Reynolds Number Testing in Support of Transport Airplane Development*, AIAA 92-3982, July 1992.

National Aeronautics and Space Administration, *National Facilities Study, Volume 2: Task Group on Aeronautical Research and Development Facilities Report*, April 29, 1994.

National Aeronautics and Space Administration, *National Facilities Study, Volume 2A: Facility Study Office on the National Wind Tunnel Complex Final Report*, April 29, 1994.

National Aeronautics and Space Administration, *National Facilities Study: Summary Report*, April 29, 1994.

Rubbert, Paul E., *CFD and the Changing World of Airplane Design*, AIAA paper, September 1994 (to be published).

U.S. Industry Team Paper, *New Subsonic and Transonic Wind Tunnel Complex*, July 1994.

FOOTNOTES

The TSWT achieves a Reynolds number of 28.2 million at mach 1.0, a pressure of 5 atmospheres, and a temperature of 100 F. The reference chord used is 1.31 ft.

[2] Transonic cruise ranges from Mach 0.75 to 0.90.

[3] The current level of understanding of the physics of high speed flows provides designers with the necessary tools to use in re-lofting the wing lines to optimize cruise performance. The TSWT will complement this by providing the experimental data necessary to guide the design modifications.

[4] Flaps, slats, ailerons, elevator, rudder, etc.

[5] The LSWT has a maximum full span Reynolds number of 20.4 million at Mach 0.3, 5 atmospheres pressure, and 100 F in a 20-ft by 24-ft test section. The full span reference chord used is 2.19 ft. Semi-span models can increase the Reynolds number to 35 million.

[6] NFS, Volume 2, p. 4.

[7] The maximum Reynolds number of the LSWT for semi-span models.

[8] Performance includes passenger and cargo payload, range, fuel consumption, and cruise speed.

[9] The effect on the test data resulting from using heavy gases, however, is not fully understood. The use of heavy gases as a test medium can increase the Reynolds number roughly by a factor of two because the heavy gas density to viscosity ratio is greater than that of air.

[10] Full-scale rotorcraft, Short Takeoff and Vehicle Landing (STOVL) and acoustic tests are performed in these facilities.

[11] Cryogenic wind tunnels super cool the air (-300 F) by injecting cold nitrogen into the air flow. The low temperature increases the Reynolds number, thus enabling the high Reynolds number capability of tunnels like the NTF and FTW. The low temperatures, however, result in poor productivity largely due to the associated difficulties in handling the models at these temperatures.

[12] The maximum pressure of the TSWT will be 5 atmospheres.

[13] At the NASA Ames 12 ft tunnel the NFS projects productivity can be

increased twofold "with aggressive pursuit of model handling, data acquisition, and control system modifications."

[14] The Ames 12-ft tunnel has been demolished and reconstructed. The new tunnel will have a maximum pressure capability of 6 atmospheres which will yield a Reynolds number of 12 million /ft at Mach 0.3. Additionally, the new control system and test section design will assist in attaining a 4 polar / occupancy hour productivity goal for the new facility.

[15] General Accounting Office, *European Aeronautics — Strong Government Presence in Industry Structure and Research and Development Support*, GAO/NSIAD-94-71, March 1994.

[16] New Subsonic and Transonic Wind Tunnel Complex, July 1994, p. 8.

[17] These tunnels are: ONERA F-1, DRA 5-m , DNW, ARA Bedford, KKK, and ETW.

[18] NFS, Volume 2, Appendix 3, p. 10.

[19] The National Facility Study explored several design concepts for the NWTC. The facility recommended and discussed here is Option D-5 of the report.

[20] The Boeing Company, General Electric Aircraft Engines, Lockheed Corporation, McDonnell Douglas Corporation, Northrop, Grumman, and United Technology Corporation (Pratt & Whitney).

[21] New Subsonic and Transonic Wind Tunnel Complex, p. 22

[22] NFS, Volume 2A, Attachment 2.

[23] The probable sites in California, Tennessee, and Virginia are NASA Ames Research Center, the Air Force's Arnold Engineering Development Center (AEDC) in Tullahoma, and NASA Langley Research Center, respectively.

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March 8, 1995

Rep. James Sensenbrenner
US House of Representatives
Chairman, Subcommittee on Space & Aeronautics
Washington, D.C. 20515

Dear Rep. Sensenbrenner:

We very much appreciated being asked to testify to your subcommittee at the March 13, 1995 hearing concerning the proposed FY 95 budget and institutional changes in NASA. I regret that we could not attend, due to prior commitments.

Enclosed please find a statement from me for the record. We appreciate your consideration of it.

Sincerely,

Louis Friedman

LF:iw

STATEMENT TO HOUSE COMMITTEE ON SCIENCE
SUBCOMMITTEE ON SPACE AND AERONAUTICS

DR. LOUIS FRIEDMAN

EXECUTIVE DIRECTOR, THE PLANETARY SOCIETY - MARCH 13, 1995

The NASA budget proposal includes severe cuts; in our opinion too severe. But recognizing that it is unlikely that Congress will make budget additions, we support the Administration request, including the bold institutional reform being initiated by the NASA Administrator. That reform is the Agency's best hope of successfully coping with the reduced budget. Even with cuts, the changes in NASA have yielded a sense of vitality and hope for the future. To illustrate that let me describe three recent personal experiences with NASA scientists and engineers working on new missions.

The first occurred on a visit to Moscow last November. I met a number of the American engineers now living in Moscow and working on the international Space Station Alpha project. You can imagine the change in their lives, and those of their families, as they moved from Houston or Huntsville, and experienced their first Russian winter. They felt a new sense of vitality. After years of frustrating talk, they were finally working and creating something real for humankind's exploration of space. And most surprising to me, almost all of these people -- many of whom had never travelled abroad -- were very positive about their working experience with the Russians. They respected Russian talents and efforts, and felt that a real team had been created working together on a new space venture.

The second was at a meeting of the Mars Science Working Group (SWG), charged with coming up with a plan for a NASA program of small robotic missions to explore Mars. That program begins next year with the dual launches of Pathfinder and Global Surveyor, and then continues in 1998 with a Surveyor lander and orbiter. The Russians have their own launch next year of Mars 96, and under the agreement of the Gore - Chernomyrdin Commission, they are working with NASA and JPL to carry out "Mars Together," beginning in 1998. The plan being studied by the Mars SWG also includes missions by the Japanese in 1998, and by the European Space Agency in 2003. There was a tremendous feeling of vitality at the meeting. Figurative applause broke out when their charge from the NASA leadership was cited: Two missions per launch year, orbiters and landers, new experiments, international cooperation, and sharing both engineering options and science opportunities -- all endorsed by their leadership. Albeit, the missions will be small, and the budget very constrained. They include extraordinary technical challenges; ones which, we believe, can be met.

The third was just a couple of weeks ago: at the announcement of the selection of the third in the Discovery series of planetary missions. 28 creative proposals were submitted from universities, NASA centers, industry and, in some cases, individuals, working together on missions aimed at targets throughout the solar system. The process brought out many innovative and clever ideas for low cost missions and experiments. Again, vitality was in the air: missions were going to be launched every year in Discovery! This from a nation which launched only four planetary missions since 1979.

Why do I cite these three experiences? To convey to you in personal terms how NASA is changing. There is a sense -- in NASA, and in the public mind, that the Agency is being revitalized already. More is being accomplished for less. The Hubble repair mission and the shuttle-Mir flight have contributed to that feeling.

Years ago The Planetary Society testified to Congress saying that a focus on bigger budgets for NASA was a mistake, and that a focus on missions, programs and accomplishments was more important. The validity of that assertion is being proved. The NASA budget has dramatically shrunk, but more is to be accomplished within it.

Despite our support for the current process, we do not advocate a smaller budget. In fact, as you well know, the currently proposed budget -- with its nearly 40% less plan from that of just six years ago, will cause huge disruptions in NASA and in the country. Many jobs will be lost and capabilities eliminated. Missions which are already constrained to the limit could be lost. They will certainly be lost if the budget is shrunk further. Mr. Goldin has taken on the challenge of cutting the agency's budget but keeping its program intact. Many are skeptical he can succeed -- but everyone wants him to. We need a NASA that does more, not less.

The Government Accounting Office report which said that NASA's plate was too full, and that they should reduce the number of activities missed the mark. An oversized NASA, with an infrastructure created during the Apollo program but doing fewer missions, is exactly the opposite of what you want. You do not want a big Agency doing few things; you want a lean Agency doing many things. The number of missions per person, per infrastructure size, per dollar should be high -- not low. This is what the NASA reform is all about.

There is a sense of vitality because Americans are finally getting additional long-duration experience in Earth orbit, that the station is really under construction, that three missions to Mars are scheduled for next year (two American, one Russian, with major European participation), that the U.S., Japan, Russia and European countries are working on plans for every Mars launch opportunity for the foreseeable future, and that new missions of **Discovery** (to a Near Earth Asteroid and to the Moon) are in development.

It is a fragile vitality -- the NASA budget proposed for 1996, has a projected run-out in the year 2000 which is 40% less than the projected run-out made in 1990. That's a cutback of nearly half in the plan. Tens of thousands of jobs will be lost, even as these new missions and new programs begin. National support to science and technology is very low, opportunity for young people is vanishing rapidly. Hiring freezes abound, retirements are being forced. The new programs are taking technical risks because they are being constructed at low cost and with new technologies. We hope the low cost will balance out the risks. Some of our best and brightest are seeing their careers disrupted; for example,the space scientists at Ames Research Center, the mission controllers at

JPL, the shuttle team at Johnson Space Center. They face each working day knowing their jobs are at risk, even as they work on these new endeavors for America.

We wish there was a little more resiliency in the budgeted program, we wish that the jobs of bright, creative people were not threatened. We believe that losing capabilities, even in the name of efficiency, is not good for the country. Decisions in the next few months will determine our exploration capabilities for decades. But, we are mindful of the difficulties you have in meeting budget pressures. Thus rather than argue for increased budget, we argue for stability and support of the new NASA, for thoughtful and insightful efforts to preserve a program of unparalleled achievements in planetary exploration preparing new accomplishments in science and new exploration every year. More than anything else, NASA represents the seeking of new knowledge, and the exploration of the unknown. More than any other attribute the American people want a NASA of achievement and excellence. Your help to them in that effort is important. We hope that the Congress will support the reform of NASA, the development of the ethic to do more for less, and the return of the "can do" Agency that made us so proud in the 1960s.

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